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Geology of the Agassiz Stratabound Au-Ag Deposit, Lynn Lake, Manitoba

By M.A.F. Fedikow

Manitoba
Energy and Mines
Geological Services

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Winnipeg, 1986

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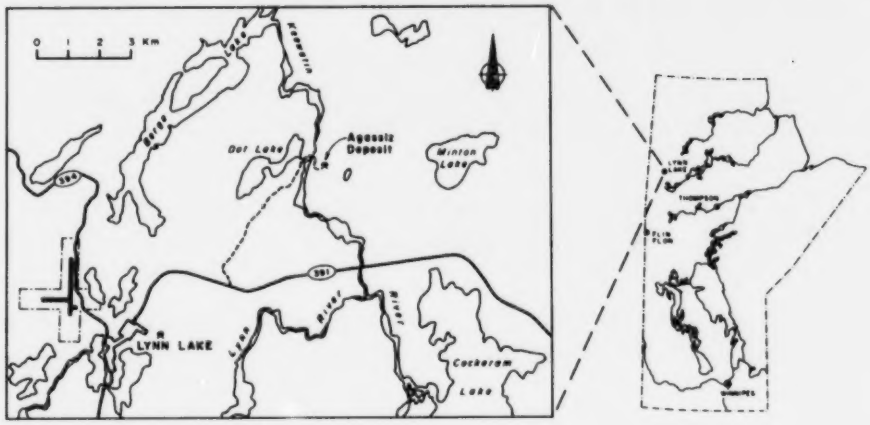

Figure 1. Location map for the Agassiz stratabound Au-Ag deposit, Lynn Lake, Manitoba.

INTRODUCTION

This study of the geological setting of the Agassiz stratabound Au-Ag deposit represents part of the results of mineral deposit investigations initiated in 1982 in the Lynn Lake area (Fedikow and Gale, 1982). The studies at Agassiz were prompted by the initial description of the deposit by Milligan (1960) and the recognition of its exhalative-syngenetic character by Koo (1976). As a result, a program of diamond drill core logging and sampling was commenced in 1982 (with the permission of Sherritt-Gordon Mines Ltd.) in order to (i) develop a working geological model for the deposit, (ii) examine the geochemistry of the host rocks for mineralization-related alteration, (iii) determine the genesis of the deposit, and (iv) evaluate the potential of the northern belt of the Lynn Lake greenstone belt for repetitions of Agassiz-type mineralization. Interpretation of Input and vertical field gradiometric surveys in conjunction with geological mapping by field parties of Sherritt Gordon Mines Ltd., Manitoba Mineral Resources Ltd., and the Geological Services Branch as well as a compilation of diamond drilling results from cancelled assessment files indicates that the host rocks to the Agassiz deposit form a stratigraphic sequence with an approximate 65 km strike length. Subsequent to the recognition of the regional extent of the Agassiz stratigraphic succession, i.e., the Agassiz Metallotect, and the paucity of outcrop associated with the 65 km zone, investigations were commenced into determining the suitability of certain surficial geochemical sampling mediums for use in geochemical exploration for Agassiz-type Au mineralization. Preliminary results of biogeochemical and basal till studies have been published (Fedikow et al., 1984). A final report describing the vegetation geochemical signature of the Agassiz deposit (Fedikow, 1985) has been published. A preliminary report dealing with peat bog geochemical studies is in preparation.

Basal till studies represent an on-going program; however, a final report describing till petrographic and geochemical results from the Farley Lake area has been published (Nielsen and Graham, 1985). An immobile element study designed to examine the genesis of the high Mg-Ni-Cr basaltic rocks ("picrite") has been initiated.

The geology of the Agassiz deposit and the nature of the mineralization is based upon observations from diamond drill core since outcrop is scarce in the vicinity of the deposit. These observations are supported by thin sections, major and trace element analyses, X-ray diffraction, electron microprobe and reflected light ore microscopy.

Recently, Sherritt Gordon Mines Ltd. have renamed the Agassiz deposit. Officially it is known as the MacLellan Mine; however, owing to a long usage of the name "Agassiz" in presentations and various reports the deposit will be referred to as the Agassiz deposit in this report.

EXPLORATION HISTORY REVIEW OF THE AGASSIZ DEPOSIT

The Agassiz deposit area (Fig. 1) was originally staked by independent prospectors in 1946 probably as a result of the interest generated by the discovery of the Farley, A, and EL Ni-Cu deposits. The Agassiz property was optioned to Noranda in 1947 and a program of geological mapping and magnetometer surveys was undertaken. The option was cancelled in 1948 and the claims lapsed in 1950. Later that year prospectors restaked the ground and between 1950 and 1955 some trenching and test pitting were done. Agassiz Mines Ltd. was incorporated in 1955 to develop the claims and in the same year undertook 648 m (2,127') of diamond drilling to test the magnetic anomalies delineated by Noranda in 1947. Preliminary results from 2 diamond drill holes indicated low gold, silver and zinc concentrations but with up to 0.12% Ni. A third drill hole indicated 2.5 g/tonne Au, 11.1 g/tonne Ag and 4.5% Zn. An electromagnetic survey was conducted in 1955 and later that year the property was optioned to Newkirk Mining Corporation who assigned it to Aumaque Gold Mines Ltd. In 1956 a resistivity survey was conducted over part of the property and 3373 m (11,067') of diamond drilling from 25 holes was undertaken to test weak electromagnetic conductors. Encouraging results for gold were obtained over intersections ranging from 0.6 to 2.4 m (2' to 8'). In 1958 the property was optioned to Consolidated Manitoba Mines Ltd. and between 1958 and 1959 a further 20 ddh totalling 2568 m (8,426') were drilled. Results were disappointing and the option lapsed in 1959. In 1960 Rayrock Mines Ltd. conducted geophysical surveys over part of the property but with inconclusive results. The Agassiz property remained dormant until 1965 when Agassiz Mines Ltd. initiated a diamond drilling program which by 1967 totalled 12 446 m (40,833') from 52 diamond drill holes.

This drilling enabled the delineation of 1.3 million tonnes of 10.0 g/tonne Au and 31.3 g/tonne Ag. In 1969 Agassiz Mines Ltd. became Royal Agassiz Mines Ltd. That year a 3-compartment shaft was sunk to the 149 m (488') level. By 1971 a total of 21 336 m (70,000') of diamond drilling from 105 drill holes had outlined 2.1 million tonnes of drill-indicated and geologically inferred mineralization grading 10.0 g/tonne Au and 37.6 g/tonne Ag. In 1977 Royal Agassiz Mines Ltd. became Agassiz Resources Ltd. and in 1979 the property was transferred to Comiesa Corporation who then optioned the property to Sherritt Gordon Mines Ltd. During 1980, 16 002 m (52,500') of diamond drilling was undertaken by Sherritt Gordon Mines Ltd. and in 1981 the shaft was deepened to 256 m (840') with 152 m (500') of drifting on the 244 m (800') level. In 1983, diamond drilling to confirm ore reserves was undertaken by Sherritt Gordon Mines Ltd. with funding shared by the Federal and Provincial Governments. To date, three mineralized zones have been delineated and geological reserves above the 1600' (488 m) level indicate 2.9 million tonnes at 5.2 g/tonne Au and 11.8 g/tonne Ag. Mineable reserves using cut and fill mining methods above the 1200' (366 m) level are quoted as 1.5 million tonnes of 6.3 g/tonne Au and 16.0 g/tonne Ag (Mining Journal, 1985).

REGIONAL GEOLOGY

The regional geology of the Lynn Lake area has been described by Gilbert et al. (1980). The following discussion has been summarized primarily from their report.

The host rocks to the Agassiz Au-Ag deposit occur within the Lynn Lake greenstone belt, a sequence of metamorphosed volcanic, sedimentary and plutonic rocks, with maximum dimensions of 130 km in length and 60 km in width (Fig. 2). This belt is located at the centre of a larger lithostructural belt extending for 500 km from La Ronge, Saskatchewan (Johnson, 1979) northeast to Partridge Breast Lake, Manitoba (Corkery and Lenton, 1979). The volcanic and sedimentary rocks in the Lynn Lake greenstone belt have been assigned to the Wasekwan Group (Bateman, 1945) and have an Aphebian age of deposition, intrusion and metamorphism (Clark, 1980). Wasekwan Group rocks have been intruded by small subvolcanic plutons and later folded, faulted and then intruded by larger mafic and felsic pl ns. The Wasekwan Group is unconformably overlain by sandstone and a conglomerate of the Sickle Group (Norman, 1933).

The Wasekwan Group rocks of the Lynn Lake greenstone belt are subdivided into two distinct structural belts separated by large, ovoid granitic intrusions. The "northern belt" is dominated by mafic volcanic rocks with intercalations of felsic and intermediate units. Chemically, the mafic volcanic rocks are distinct from those of the "southern belt" and comprise tholeiitic basalt and andesite interlayered with aluminous (greater than 18% Al_2O_3) basalt and andesite. The northern belt has been subdivided into six distinct lithostratigraphic divisions, arbitrarily designated A through F. Division A represents the lowermost unit and comprises a 2400 m thick lens of rhyolitic rocks with subordinate mafic volcanic rocks and conglomerate. These rocks are overlain by a

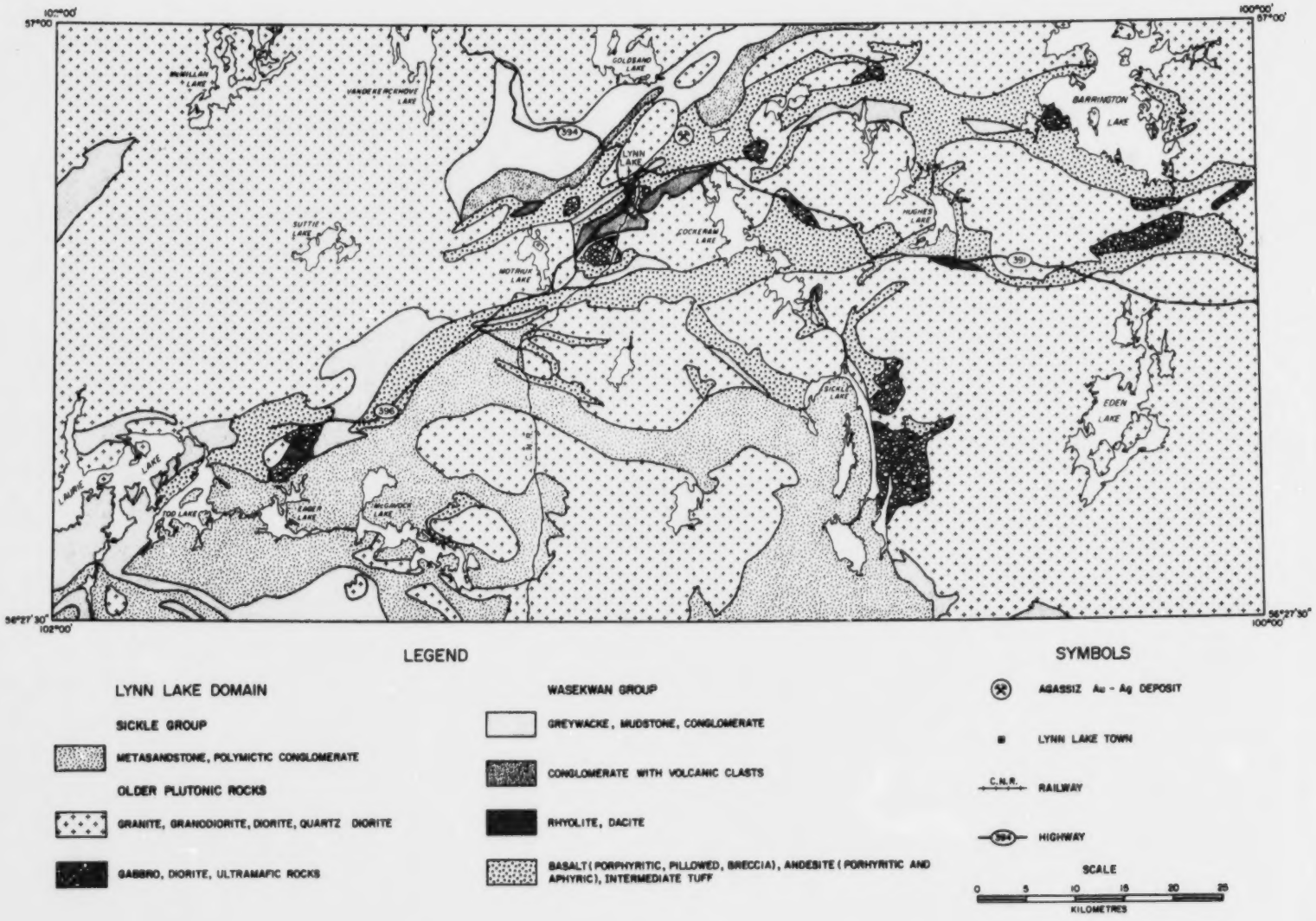

Figure 2: Regional geology of the Lynn Lake greenstone belt (after Gilbert et al., 1980).

suite of mafic to felsic volcanic flows and fragmental rocks of Division B that are in turn overlain by a sequence of fine- to coarse-grained sedimentary rocks characterizing Division C. Division D is represented by basaltic flows and flow breccia with subordinate mafic tuff, felsic fragmental rocks and iron formation. This division is particularly consistent over the length of the "northern belt" without significant lateral facies changes. It, in part, forms the host rocks for the Agassiz mineralization. Division D is overlain by mafic tuff, flows and subordinate volcanic breccia and greywacke of Division E as well as rhyolite flows and breccias and subordinate volcaniclastic rocks of Division F. Iron formation overlies the uppermost Wasekwan Group rocks and along the northwestern margin of the northern belt. This iron formation is unconformably overlain by conglomerate of the Sickle Group.

The southern belt comprises thick sections of tholeiitic, aphyric and porphyritic basalt topped by thick turbidite units in the west and felsic to mafic volcanic rocks to the east. Small areas of greenstone occur to the south of the southern belt in predominantly granitic terrane.

The structure of Wasekwan Group rocks in the Lynn Lake greenstone belt is characterized by isoclinal folding on steeply dipping east-northeast-trending axial surfaces. Pre-Sickle granitic intrusions, dated at 1940 ± 74 Ma and 1825 ± 210 Ma (Clark, 1980), truncate the folds. The northern belt appears to be dominantly monoclinal with a northwards stratigraphic younging direction. The southern belt is characterized by large, early folds with axial traces parallel to the regional foliation. Conglomeratic turbidites filling tectonic depressions in the western part of the Lynn Lake greenstone belt suggest that block faulting occurred during the deposition of the Wasekwan Group sedimentary rocks.

The metamorphic grade of Wasekwan Group rocks is variable. In the northern belt lower to middle amphibolite facies metamorphism is developed with the mafic volcanic rocks characterized by the mineral assemblage hornblende and/or cummingtonite and oligoclase or andesine ± quartz ± epidote ± biotite ± sphene. Sedimentary rocks are characterized by the mineral assemblage quartz + oligoclase + biotite ± hornblende ± garnet ± epidote ± magnetite ± chlorite ± muscovite. In the southern belt intermediate volcanic rocks in the east are characterized by the low grade greenschist metamorphic mineral assemblage of albite + epidote + quartz + actinolite ± biotite ± chlorite ± leucoxene ± carbonate. Sedimentary rocks of the southern belt contain the mineral assemblage quartz ± plagioclase ± garnet ± biotite ± muscovite ± staurolite ± cordierite ± andalusite.

For a detailed petrochemical report on the volcanic rocks in the Lynn Lake greenstone belt the reader is referred to Syme (1985).

LOCAL GEOLOGY

Introduction

This description of the geological setting of the Agassiz deposit is based primarily on observations from diamond drill core. Outcrop in the vicinity of the deposit is scarce.

The interlayered clastic and chemical sedimentary rocks and the high Mg-Ni-Cr basaltic rocks that characterize the Agassiz deposit host rocks occur between thicker sequences of aluminous fragmental basalt and mafic debris flows. The local geology of the deposit is described initially in terms of the rocks that stratigraphically overlie and underlie the Agassiz Metallotect, and secondly, in terms of the hanging wall and footwall to the Agassiz deposit.

The geology depicted in Figures 9, 10 and 11 represents a much simplified version of actual observations made during diamond drill core logging. The simplification was required due to the thinly bedded nature of the rocks within the mineralized zone and the difficulty in visually depicting this information. A representative diamond drill core log (DDH U82-5) is presented in Appendix I and reflects the amount of detail in the section. Graphic logs complete with assay data for all drill holes used in the construction of the geological cross-sections for this report are available for viewing upon request.

The major and accessory minerals that characterize each of the major rock units at the deposit are described in Table 2.

Stratigraphically Overlying and Underlying Sequences - Agassiz Metallotect

The Agassiz Metallotect concept has evolved since the initial re-examination of the geology of the Agassiz deposit (Fedikow and Gale, 1982). With ongoing field examinations and discussions with geologists representing Sherritt Gordon Mines Ltd. (Lynn Lake) and Manitoba Mineral Resources this concept has progressed from the 1500 m of drill proven mineralized stratigraphy characterizing the Agassiz deposit to 65 km of strike length (Fedikow, 1983; Fedikow et al., 1984; Fedikow, 1984, 1985). The main component of the Metallotect, the interlayered high-Mg-Ni-Cr basalt, sulphidic siltstones and iron formations, is observed over the entirety of the Metallotect and appears to be a unique and well-defined sequence in this area, although facies changes over this 65 km zone are apparent. It is beyond the scope of this report to describe the overlying and underlying rocks to the Metallotect over the entire 65 km; only the geological characteristics of the stratigraphically overlying and underlying rock sequences to the Agassiz deposit host rocks at the deposit are presented here. Figure 3 illustrates the Metallotect concept and more specifically the overlying rocks and the underlying rocks to the north and south, respectively of the Agassiz Metallotect and the Agassiz deposit.

The rocks overlying and underlying the Agassiz Metallotect comprise amygdaloidal, porphyritic, aphyric, massive and fragmental mafic volcanic rocks. The fragmental rocks have been termed autoclastic breccia (Gilbert et al., 1980) and agglomeratic tholeiitic basalt (Fox and Johnson, 1981). The volcanic breccias are polymictic with up to four lithologic fragment-types observed. These include (i) quartz-phyric rhyolite, (ii) dark green amygdaloidal and porphyritic basalt, (iii) lighter green aphyric basalt, and (iv) dark green amygdaloidal basalt. The fragments are angular to rounded, slightly elongate with maximum dimensions of

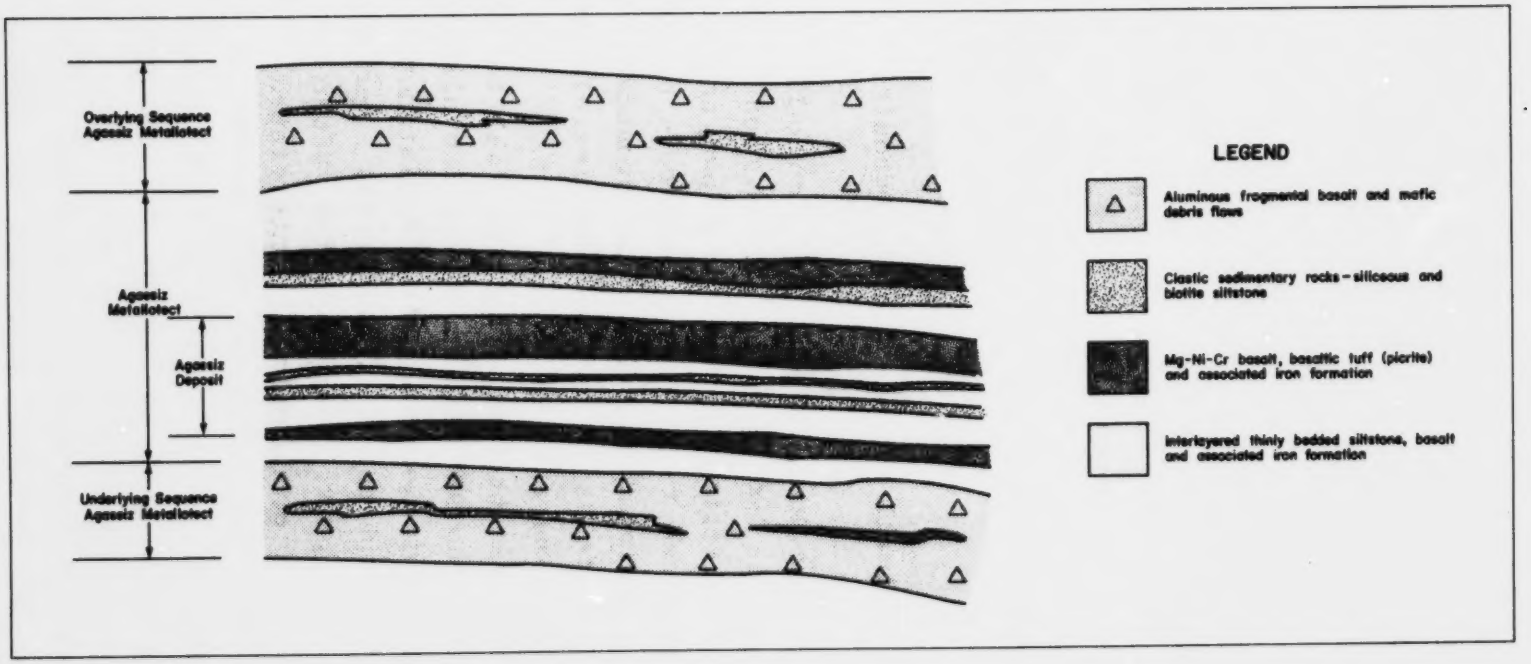
Overlying Sequence Agassiz Metallotect
Agassiz Metallotect
Agassiz Deposit
Underlying Sequence Agassiz Metallotect
LEGEND
Aluminous fragmental basalt and mafic debris flows
Clastic sedimentary rocks - siliceous and biotite siltstone
Mg-Ni-Cr basalt, basaltic tuff (picrite) and associated iron formation
Interlayered thinly bedded siltstone, basalt and associated iron formation

Figure 3: Schematic illustration of the Agassiz Au-Ag deposit host rocks (Agassiz Metallotect) and the overlying and underlying rock sequences.

30 cm. Amygdales are dominantly quartz ± feldspar, attain maximum dimensions of 0.5 cm, and generally display a uniform distribution within the fragments. The fragments are matrix-suppoprted and may be partially or totally epidotized. In the immediate vicinity of the deposit, near the contact with the underlying clastic and chemical sedimentary rocks and high Mg-Ni-Cr basalts, fragment outlines are barely discernible due to abundant iron oxide staining. The breccia matrix is characterized by a lower concentration of amygdales and/or feldspar phenocrysts. The breccia units are commonly 5 - 7 m thick and conformably overlie the interlayered clastic and chemical sedimentary rocks and high Mg-Ni-Cr mafic volcanic flows and tuffs that characterize the Agassiz Metallotect.

Hanging Wall and Footwall Rocks - Agassiz Deposit

The immediate hanging wall and footwall rocks to the Agassiz mineralization are 3 - 8 m thick high Mg-Ni-Cr mafic units interpreted to represent basaltic flows and tuff. These rocks are characterized by 3 - 5 mm amphibole grains set in a fine- to coarse-grained chlorite-rich groundmass. Garnet, quartz, plagioclase feldspar and opaque minerals make up the remainder of the minerals in these rocks. The amphibole content varies from scattered amphiboles (5%) to interlocking amphiboles that make up 90% of the rock. The alignment of the long axes of the amphiboles can impart a distinct foliation to the rocks. The amphiboles (hornblende, ferro-actinolite, actinolite) are, in part, pseudomorphous after clinopyroxene and the chlorite-rich groundmass is interpreted to represent the devitrified and metamorphosed equivalent of a volcanic glass. Alternatively, the chlorite-rich groundmass may represent the metamorphosed equivalent of a secondary mineral assemblage after olivine (Fox and Johnson, 1981); olivine has not been observed in thin sections of these rocks. Both the hanging wall and the footwall volcanics are distinctive from

the high Mg-Ni-Cr rock units in the mineralized zone in that they are more thickly bedded. Quartz-carbonate veins containing subhedral to euhedral pyrite are present in both the hanging wall and footwall rocks.

Table 1 gives representative silicate whole rock and trace element analyses of the hanging wall and footwall rocks. Their distinctive major element chemistry is reflected by their separation from the aluminous basalts that form the overlying and underlying sequences to the Agassiz Metallotect and from the mineralized siltstones on $MgO-CaO-Al_2O_3$ and $Fe_2O_3(T) + TiO_2-MgO-Al_2O_3$ ternary diagrams (Fig.4). The rocks stratigraphically underlying the mineralized zone have been described by Fox and Johnson (1981) as <u>tholeiitic picrite</u> characterized by a distinct mineralogy when compared to the same rocks away from the deposit area. The footwall sequence away from the deposit is marked by ferroactinolite porphyroblasts set in a matrix of carbonate, opaque minerals and plagioclase feldspar whereas in the immediate deposit area the same rocks are effectively actinolite-chlorite-sulphide schists.

The determination as to whether these rock units are volcanic in origin is based upon outcrop and thin section evidence. The occurrence of two discrete fragment-types in outcrop from the Dot Lake area suggest that these rocks are volcanic in origin and have been reworked. Figure 5 indicates the presence of rounded, 2 - 10 cm long x 1 - 4 cm wide amygdular fragments in a soft, chlorite-rich matrix. The amygdales are 1 - 2 mm in diameter, tightly packed and filled with feldspar. This type of fragment is reminiscent of flow-top breccia. The second fragment type (Fig. 6) is 1 - 3 cm x 1 - 2, is angular to subrounded and compositionally similar to the chlorite-rich matrix of the unit. The nature of the second fragment is suggestive of some degree of reworking of these rocks - a hypothesis that is supported by thin section

Table 1: Silicate whole rock and trace element analyses of representative samples of the major rock units at the Agassiz Au-Ag deposit, Lynn Lake.

	(3) amygdaloidal basalt			(2) biotite siltstone			siliceous siltstone			(1) high-Mg basaltic rocks		
	AGC 1	AGC 25	AGC 34	AGC 240	AGC 276	AGC 360	AGC 538	AGC 543	AGC 663	AGC 545	AGC 557	AGC 688
SiO_2	49.5	50.7	48.6	45.4	45.2	48.9	74.5	76.2	73.3	41.9	44.8	40.6
Al_2O_3	20.8	19.1	19.5	26.0	23.2	17.3	12.1	12.4	11.8	6.9	8.2	8.4
$Fe_2O_3^T$	10.3	11.1	13.5	7.8	7.6	7.5	4.3	2.8	6.2	12.7	13.5	13.2
MnO	0.13	0.18	0.19	0.16	0.27	0.26	0.05	0.02	0.08	0.22	0.24	0.26
CaO	9.2	9.2	8.6	3.6	7.2	9.4	1.7	0.7	2.5	10.5	9.8	9.4
MgO	3.3	5.4	4.4	8.3	7.3	5.0	2.2	1.6	1.1	19.4	17.8	19.6
Na_2O	4.1	2.4	3.0	0.7	0.3	0.7	1.3	1.9	2.7	0.1	0.2	0.4
K_2O	0.5	0.3	0.4	5.3	5.6	5.0	2.3	2.3	0.9	0.0	0.1	0.0
P_2O_5	0.04	0.05	0.04	0.03	0.09	0.01	0.08	0.04	0.10	0.11	0.10	0.09
TiO_2	1.0	0.7	1.1	0.3	0.2	1.2	0.3	0.3	0.3	1.2	1.6	1.1
LOI	0.8	0.9	0.6	2.1	2.9	4.3	1.3	1.4	0.9	7.2	3.9	6.7
TOTAL	99.7	100.0	99.9	99.8	99.9	99.7	100.1	99.7	99.9	100.2	100.2	99.5
Cr	25	51	196	66	174	80	25	25	25	1857	1551	1309
Ni	24	10	137	89	141	34	10	10	10	1033	897	955

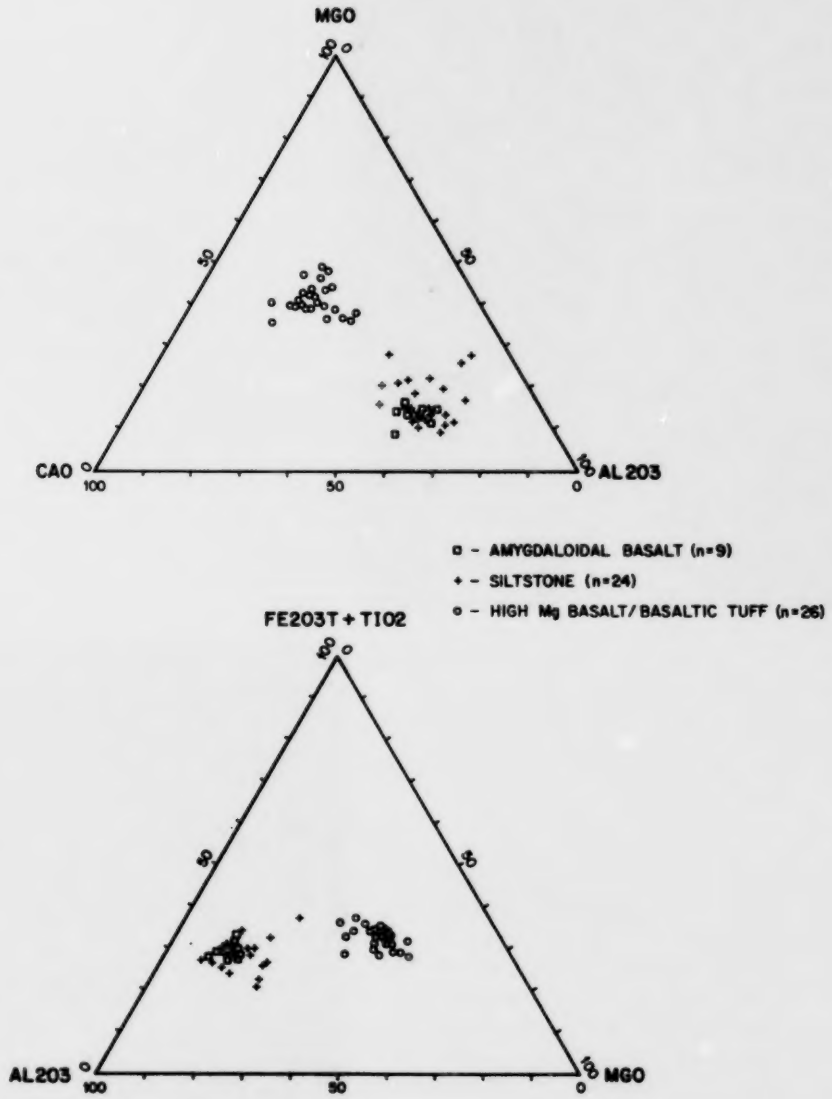

Figure 4: Ternary diagrams illustrating major element compositional variation between the common rock units at the Agassiz Au-Ag deposit.

Figure 5: Fragment types in the high Mg-Ni-Cr basalt ("picrite") at Dot Lake, vicinity of the Agassiz deposit. Note: a - tightly packed feldspar-filled amygdular and rounded fragments.

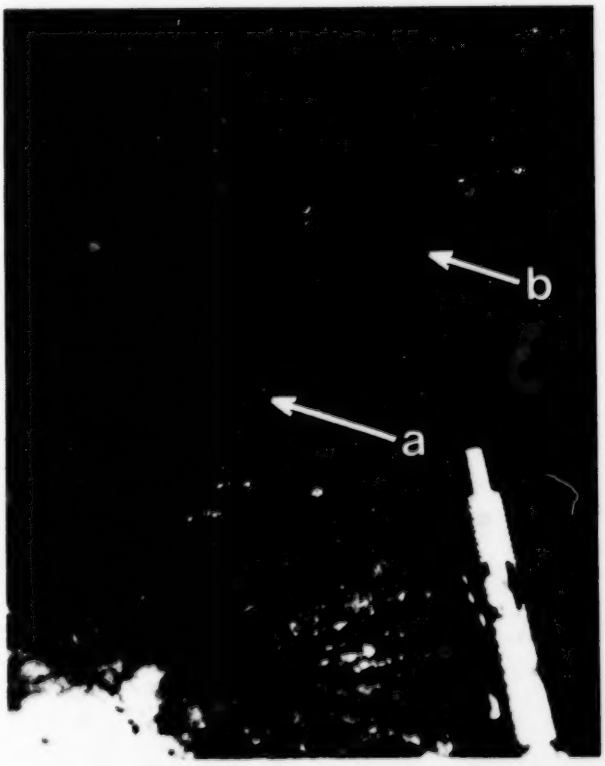

Figure 6: Reworked fragments in the high Mg-Ni-Cr basalt ("picrite") at Dot Lake, vicinity of the Agassiz deposit. Note: a and b - poorly sorted, angular to rounded reworked fragments compositionally similar to the picrite matrix.

examination of these rocks. Sections cut from the siltstone-basalt contact indicate mixing of these two units has occurred, an observation which is substantiated by high Ni and Cr contents in the siltstone (Table 1). Pillowed high Mg-Ni-Cr basalts within the Metallotect have also been reported (M. Taylor, Manitoba Mineral Resources Limited, pers. comm.). The hanging wall and footwall sequences are interpreted, therefore, to represent basalt flows and interlayered tuffs that have been, in part, reworked.

Mineralized Zone

The mineralized zone of the Agassiz deposit comprises thinly bedded interlayered biotite-rich and siliceous siltstone, oxide, silicate and sulphide facies iron formation and high Mg-Ni-Cr basalt flows and minor tuff. The siltstone, iron formations and mafic volcanic units range in thickness from 1 cm to 2 m and have been crosscut by a series of carbonate-quartz-sulphide veins. All rock units in the mineralized zone have been affected by multiple deformational events ultimately producing a northeast-trending foliation that parallels regional layering. The westward plunging mineralized zone attains thicknesses of 10 - 20 m and has been defined by diamond drilling for 1500 m along strike of the host rock units.

Reference to the simplified geological section through the Agassiz deposit (Fig. 7) indicates that the mineralized zone, characterized by significant gold and silver values, occurs at or near the basal portion of the interlayered high Mg-Ni-Cr basalts and siltstones. Each of the stratigraphic components of the mineralized zone are discussed in turn.

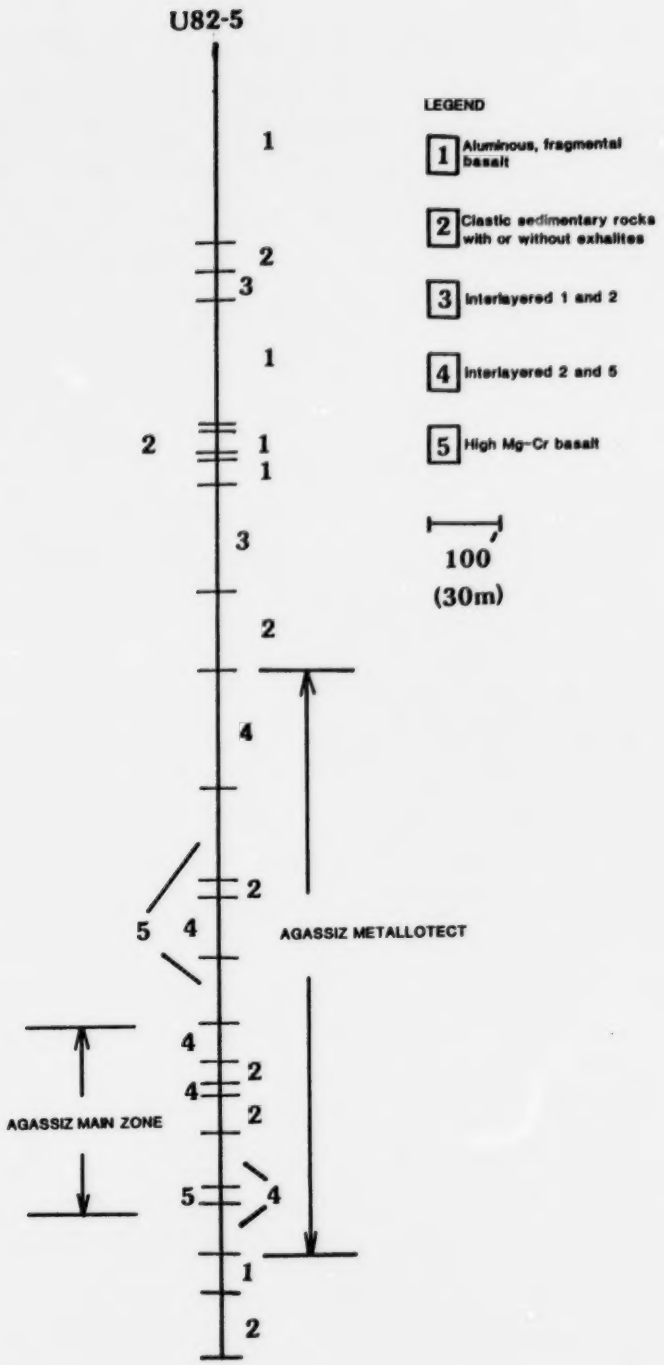

Figure 7. Simplified stratigraphic section through the Agassiz Au-Ag deposit based on DDH U82-5. The detailed log of DDH U82-5 is presented in Appendix I.

(i) Siltstone

The clastic sedimentary rocks in the mineralized zone comprise laminated to bedded normally and reversely graded siltstone, unsorted siliceous siltstone, and biotite-rich sulphidic siltstone. The graded siltstones are 5 mm to 3 cm thick whereas the unsorted siliceous siltstones range in thickness from 1 - 30 cm. The graded siltstone units are interpreted to represent products of clastic sedimentation from low density turbidity currents whereas the unsorted siltstones may have resulted from a mass flow depositional regime comprising previously sorted clastic detritus. The biotite-rich siltstones contain a higher proportion of the iron and base metal sulphide mineralization. They are interpreted as reflecting the mixing between fine grained distal turbidites as they were deposited over exhalative muds characterized by a high clay and sulphide mineral content. Coarse grained (3 - 7 mm) subhedral to euhedral magnetite crystals occur within the siliceous siltstone units and represent metamorphic coarsening of an original iron-rich component of the siltstone.

Sulphide mineralization in the siltstone units is present as disseminated grains to solid layers up to 0.5 m thick and also as fracture coatings which are interpreted to represent mobilization phenomena. The biotite siltstones contain a greater proportion of iron sulphides whereas the siliceous siltstones are characterized by disseminated arsenopyrite, sphalerite and galena in addition to pyrite and pyrrhotite. Locally the siliceous siltstone units have the appearance of chert; however, subsequent to petrographic examination and diamond drill core logging these "cherts" are interpreted to represent silicified siltstones. The presence of diffuse silica-sulphide fronts emanating from late silica-rich fractures in the "chert" support the silicification hypothesis. Thin (1 - 5 mm) chemically precipitated primary

chert units have been identified in the sequence, usually associated with finely laminated magnetite.

Mineralogically, the predominant minerals comprising the siliceous and biotite-rich siltstones are quartz, biotite, plagioclase, locally developed subhedral to euhedral staurolite porphyroblasts and opaques. Accessory minerals in the siltstones are listed in Table 2.

The mineralized zone of the Agassiz deposit has been affected by at least 3 deformational events and as a result a locally developed fragmental nature may be observed in the siltstones. The moderately sorted monolithic fragments are marked by relict fold hinges and incipient boudinage indicating the fragments are transposed layering.

The bulk compositional differences between the biotite-rich and siliceous siltstones are evident from inspection of Table 1. Higher concentrations of Al_2O_3, K_2O, MgO and LOI (biotite, sericite, chlorite), CaO and MnO (carbonate), Fe_2O_3(T) (opaques-oxides and sulphides), and lower SiO_2 (quartz) and Na_2O (plagioclase) in the biotite-rich siltstones reflect basic differences in mineralogy (provenance) and alteration mineral assemblages. The higher Ni and Cr concentrations in the biotite-rich siltstone indicate either a detrital contribution from the high Mg-Ni-Cr mafic volcanic units interlayered with the siltstones in the mineralized zone, or the introduction of Ni and Cr to the siltstones resulting from seawater-basalt ("picrite") interaction.

Most of the gold-bearing mineralization at the Agassiz deposit occurs within these siltstones.

Table 2. Petrographic descriptions of the major rock units of the Agassiz Au-Ag deposit, Lynn Lake.

ROCK UNIT	HAND SPECIMEN	MAJOR MINERALS	ACCESSORY MINERALS
(1) amygdaloidal basalt	dark green to black, fine grained chloritic matrix, quartz filled amygdales (0.5 - 3 cm); patchy rusty weathering in outcrop	plagioclase feldspar (An 30-50), hornblende, quartz	biotite, magnetite, chlorite, pyrite, epidote
(2) siltstone	white to grey, fine grained with variable biotite content; biotite occurs as 1 - 5 mm bands or patches; may contain 1 - 5 mm chert layers alternating with chlorite-amphibole-magnetite layers; disseminated and solid sulphide layers; crosscut by calcite-sulphide-quartz veinlets; silicified, carbonatized, chloritized.	quartz, biotite	staurolite, chlorite, garnet (spessartine and almandine) calcite, actinolite, hornblende, magnetite, plagioclase feldspar (An 0 - 10), potash feldspar, sericite, cordierite, epidote, dravite, zircon, sphene, rutile, pyrite, pyrrhotite, sphalerite, arsenopyrite, galena, chalcopyrite, native gold, native silver, freibergite, pentlandite, ilmenite
iron formation			
i. oxide facies	steel grey interlayered magnetite bands (12 mm) and white to beige chert bands (25 mm); disseminated arsenopyrite (2 mm) and pyrrhotite (1 mm).	quartz, magnetite	pyrrhotite, arsenopyrite, biotite, chlorite
ii. silicate facies	olive green, fine grained chlorite matrix with 5 mm - 1 cm pink garnet; occurs in 3 - 6 cm layers	chlorite, garnet (almandine), magnetite	actinolite, hornblende, calcite
iii. sulphide facies	disseminated to solid sulphide bands (2 - 15 cm) interlayered with biotite bands	pyrite, pyrrhotite, sphalerite, biotite	quartz, calcite
(3) high-Mg basalt	fine grained, olive green chlorite matrix with 1 - 5 mm actinolite porphyroblasts; disseminated magnetite, sulphides and solid sulphide layers	chlorite, actinolite, hornblende	quartz, biotite, calcite, plagioclase feldspar (An 30 - 50), cordierite, magnetite, sphalerite, pyrite, pyrrhotite, native gold, garnet (almandine)

(ii) Iron Formations

Three facies of iron formation are interlayered with the siltstone and high Mg-Ni-Cr basaltic flows and tuffs in the mineralized zone. Characteristically, the iron formations occur as laterally discontinuous, tightly folded, thin (1 - 10 cm) layers.

The oxide facies comprises interlayered 1 - 3 cm bands of chert and finely laminated magnetite with rare arsenopyrite and pyrrhotite. This unit is crosscut by non-mineralized carbonate-quartz veins. The origin of the laminated magnetite is related to exhalative precipitation of originally amorphous $Fe(OH)_3$ or FeO(OH) compounds. In the presence of organic carbon these ferric hydroxide compounds would be reduced and magnetite produced during diagenesis (Drever, 1974). The silicate facies iron formation is predominantly a chlorite-garnet (almandine)-actinolite assemblage that contains iron and base metal sulphides. Locally, the silicate facies iron formation is intercalated with 1-5 mm thick layers of fine- to coarse-grained (5 - 7 mm) subhedral to euhedral magnetite. Thin chert units are interlayered with the silicate facies iron formation which is interpreted to represent a chemical exhalative mud. The sulphide facies iron formation consists of rhythmically layered 1 mm - 5 cm bands of solid iron sulphide (pyrite, pyrrhotite) and biotite-rich laminae. This facies often displays tight folding.

The oxide and silicate facies iron formations are not hosts to significant gold and silver mineralization in the deposit although values of 3.4 g/tonne Au and 27.0 g/tonne Ag have been reported from sheared, bedded sulphide facies iron formation in the deposit. The mineralogy of the three facies of iron formation is presented in Table 2.

Typically the silicate facies iron formation is high in Mg, Ni and Cr and except for the high Mg content may represent correlatives to the high Ni and Cr concentrations introduced by hydrothermal activity to the ocean floor sediments along present-day ridges such as the East Pacific Rise (Piper, 1973; Sayles and Bischoff, 1973; Sayles et al., 1975).

(iii) High Mg-Ni-Cr Basalt Flows and Tuffs

The final lithologic component within the mineralized zone is represented by 1 - 3 m thick high Mg-Ni-Cr volcanic flows and tuffs. These units are mineralogically and chemically similar to the hanging wall and footwall basaltic rocks, but differ from these basaltic rocks in that the percentage of amphiboles is consistently greater than 80% and beds are thinner. Locally, the flows and tuffs have been silicified, carbonatized and occasionally contain 1 cm almandine garnets. Mineralization in these units occurs as disseminated blocky and acicular arsenopyrite, galena and iron sulphide in addition to sphalerite layers. Isolated 3 x 2 cm blebs of coarse grained, recrystallized iron sulphides are observed in units marked by a high percentage of amphibole porphyroblasts.

(iv) Mineralization

The highest gold and silver values in the mineralized zone of the Agassiz deposit are associated with silicification and mobilization phenomena related to the development of a post-depositional set of carbonate-quartz-sulphide veins. Sulphidic minerals observed in or adjacent to these veins

and/or their silicification halos or fronts include pyrite, pyrrhotite, sphalerite, galena and arsenopyrite. Galena is most abundant in these veins. Where the veins crosscut the sulphidic siltstones high gold assays are obtained although persistent but lower gold values are obtained from samples of silicified, arsenopyrite and galena-bearing high Mg-Cr basaltic rocks.

A recent study of the ore mineralogy of the Agassiz deposit has been published by Augsten (1985). The study represents an Honours Bachelor of Science topic undertaken in the Department of Geology at Carleton University in association with the Geological Survey of Canada. Since this study represents the most up-to-date information, the bulk of the following discussion has been derived from Augsten's thesis. Mineral identification was accomplished using reflected light microscopy, electron microprobe and X-ray powder diffractograms.

Table 3 gives a description of the opaque mineral species observed in the Agassiz deposit and their inter-relationships.

Most commonly gold and silver in the Agassiz mineralization are commonly associated with 20-30 micron-sized grains of pyrrhotite, arsenopyrite, galena, pyrite, sphalerite, ilmenite and magnetite; some grains are greater than 150 microns. As well, gold and silver can form small irregular grains or veinlets less than 10 microns in silicate host rocks or as mantling rims or fracture fillings in galena, arsenopyrite and pyrrhotite. The metals also occur as inclusions in arsenopyrite, pyrrhotite and galena; larger grains of native metals appear to be associated with arsenopyrite and galena. Specifically, the gold in the deposit occurs in the native form and as aurian silver and electrum. Silver is sited in freibergite, aurian silver, electrum,

tetrahedrite and pyrargyrite. A determination of 44.5 weight % Ag in tetrahedrite by Augsten (1985) represents one of the highest Ag contents reported for this mineral. Riley (1974) reports 42.5 weight % Ag in tetrahedrite from Mt. Isa in Australia and Zakrzewski and Nugteren (1984) reported 48.2 and 45.3 weight % Ag in tetrahedrite from the stratabound Hellefors silver deposit in Sweden. The identification of argentopentlandite by Augsten (1985) represents the first reported occurrence of this mineral in a gold deposit. Previously, it has been documented by Scott and Gasparini (1973) in the Bird River Sill and the Sudbury ores. The mineral chemistry of the native metals indicates a wide spectrum of gold-silver solid solutions associated with the Agassiz mineralization (cf. Table 3, p. 18; Augsten, 1985). Other notable trace element constituents in the native metal grains in the Agassiz deposit include Sb and Hg. The presence of Sb-rich sulphosalts and Sb-bearing ullmannite and breithauptite in the Agassiz deposit is considered to be a plausible explanation for the anomalously low Au:Ag ratio of 0.45. Using published grades of 4.8 g/tonne Au and 10.7 g/tonne Ag (Northern Miner, November 8, 1984) the Au:Ag ratio for Agassiz is 0.45, much lower than the average ratio of greater than 1 for Canadian Shield gold deposits and the 4.2 ratio quoted for gold-quartz vein gold deposits (Boyle, 1979). An increase in the mobility of Ag in the presence of abundant Sb would tend to reduce the Au:Ag ratio (Boyle, 1979). Other unusual mineral species reported by Augsten (1985) include Co-enriched pentlandite and pyrite as well as the documentation of ullmannite in the Agassiz mineralization. Normally, these minerals are associated with mineral deposits in ultramafic rocks. Exceptions to this rule include breithauptite and ullmannite from the Kolar goldfields in India (Safonov et al., 1984) and ullmannite in galena in mineralized breccia from Scotland (Patrick and Hall, 1984).

Table 3. Description of the opaque mineralogy of the Agassiz Au-Ag deposit, Lynn Lake. Data summarized from Augsten (1985).

Mineral Class	% Occurrence in Polished Sections	Size	Association	Form and Texture
COMMON SULPHIDES				
1. Pyrite	100	50μm - 0.5 m	sphalerite, pyrrhotite	Disseminated subhedral to euhedral grains and monomineralic layers; larger euhedral grains are poikilitic, embayed or corroded; fractures in monomineralic layers infilled with sphalerite and pyrrhotite.
2. Arsenopyrite	60	30μm - 40μm	pyrite; pyrrhotite and chalcopyrite inclusions	Euhedral rhomb shaped crystals; layers of aggregates of euhedral grains; forms composite layers with pyrite.
3. Pyrrhotite	50		pyrite, arsenopyrite, pentlendite	Anhedral grains and masses; interstitial to pyrite and arsenopyrite; 2 phases: (1) blades of pyrrhotite emanating from fractures or other linear features in (2) darker coloured pyrrhotite; contains exsolution sheaves of pentlandite; alteration to fine grained mixture of pyrite and marcasite ("birds-eye").
4. Galena	-	coarse grained	pyrite, pyrrhotite arsenopyrite, tetrahedrite, freibergite, pyrargyrite, polybasite, geocronite, breithauptite, ullmannite	Sutured; heals or cments micro-breccia zones and as fracture fillings; replaces pyrite, pyrrhotite and arsenopyrite; more rarely as inclusions in pyrrhotite and chalcopyrite; co-existing with electrum in fractures in arsenopyrite; usually present in many of the gold and native-metal-bearing sections.
5. Chalcopyrite	10	-	sphalerite, pyrite pyrrhotite	Veinlets or grains in silicate gangue and commonly at pyrite-pyrrhotite grain boundaries; inclusions and exsolution blebs in sphalerite; occasionally as inclusions in arsenopyrite and galena.
6. Marcasite	5	-	pyrrhotite, pyrite	Alteration of pyrrhotite.
OXIDES				
1. Ilmenite	most abundant oxide	max. 100μm	rutile	Anhedral grains and subhedral to euhedral laths; laths may be poikilitic enclosing silicate minerals; symplectic intergrowths with rutile.
2. Rutile	50	20μm	pyrrhotite, ilmenite	As disseminated subhedral to anhedral grains or aggregates of grains in lenses or layers; as needles associated with pyrrhotite.
3. Sphene	minor	-	rutile, ilmenite	Interstitial to aggregates of anhedral rutile grains.
4. Magnetite	minor	200μm	native gold	Equant anhedral grains; fractured and infilled with gold grains and veinlets.

Mineral Class	% Occurrence in Polished Sections	Size	Association	Form and Texture
SULPHOSALTS				
1. Tetrahedrite/ Freibergite ($Cu_{12}Sb_4S_{13}$)	-	10 - 150 μm	galena, chalcopyrite, sphalerite, pyrrhotite, pyrite arsenopyrite	Included by or spatially associated with galena; as 10 μm grains at the contact between galena and sphalerite, pyrrhotite, pyrite or arsenopyrite.
2. Pyrargyrite (Ag_3SbS_2)		20 - 100 μm	galena, calcite	Anhedral grains; spatially associated with and as inclusions in galena.
3. Geocronite ($Pb_5(Sb,As)_2S_8$	very rare	75 μm	galena	Anhedral grains with galena.
4. Polybasite ($Ag_{16}Sb_2S_{11}$)	rare	10 μm	galena	Andredal grains with galena.
Ni AND Ni-Sb MINERALS				
1. Pentlandite ($Fe, Ni)_9S_8$	minor	$\lesssim$10 μm	pyrrhotite	As exolution sheaths in pyrrhotite.
2. Argentopentlandite $(Fe, Ni)_{8+x}Ag_{1-x}S_8$	rare	-	pyrrhotite, sphalerite	Anhedral grains with pyrrhotite and sphalerite.
Ni AND Ni-Sb MINERALS				
3. Breithauptite (Ni Sb)	rare	-	chalcopyrite, galena pyrrhotite, tetrahedrite	As intergrowths with chalcopyrite at galena-pyrrhotite grain boundaries; also as vermiform grains in galena closely associated with similar textured tetrahedrite.
4. Ullmannite (Ni Sb S)	rare	-	chalcopyrite, galena pyrrhotite	Intergrowth with chalcopyrite as irregular bands; also at galena-pyrrhotite grain boundaries or galena-silicate boundaries; as an intergrowth with pyrrhotite in euhedral grains.
NATIVE METALS				
Gold-Electrum-Aurian Silver	-	20 - 30 μm; some greater than 150 μm	arsenopyrite, galena, pyrrhotite, tetrahedrite, freibergite, pyrargyrite, ilmenite, magnetite	Gold as: (i) inclusion in pyrrhotite; (ii) infilling fractures in arsenopyrite; (iii) electrum with galena in sutured grains; (iv) gold rimming arsenopyrite; (v) tetrahedrite in sutured galena; (vi) freibergite in galena; (vii) pyrargyrite in calcite-filled vugs.

The gold, silver and sulphide mineralization that characterizes the Agassiz deposit can be subdivided into an East, Cental or Main, and West Zone (Fig. 8). These subdivisions are based upon geological observations primarily from diamond drill core but also from underground inspection in the Central Zone.

(1) Central Zone

Mineralization in the Cental Zone is characterized by up to 1 m of 10 - 25% gold-bearing iron sulphides hosted in biotite-rich and siliceous siltstone and accompanied by minor arsenopyrite, sphalerite, galena and rare chalcopyrite. Some 1 m intervals of 30 - 35% pyrite are also observed. The Central Zone mineralization is truncated by the North Shear (Fig. 9), an ill-defined series of late, en echelon faults with accompanying chloritization and silicification. This fault system is a reflection of a post-depositional deformation and its metallogenetic significance to the deposit is such that it may be responsible, in part, for gold mobilization and subsequent re-siting in dilatant zones coeval with the formation of the North Shear. Silicification of the siltstones and patchy but locally intense carbonate alteration of the high Mg-Cr basalts represent the most common types of alteration in the Central Zone.

(2) West Zone

The West Zone is similar in geology and mineralization-alteration characteristics to the Central Zone. The gold-bearing mineralization defined by diamond drilling is thinner (Fig. 10) although the geological environment represented by interlayered siliceous and biotite-rich siltstone and high Mg-Cr basalts with accompanying silification

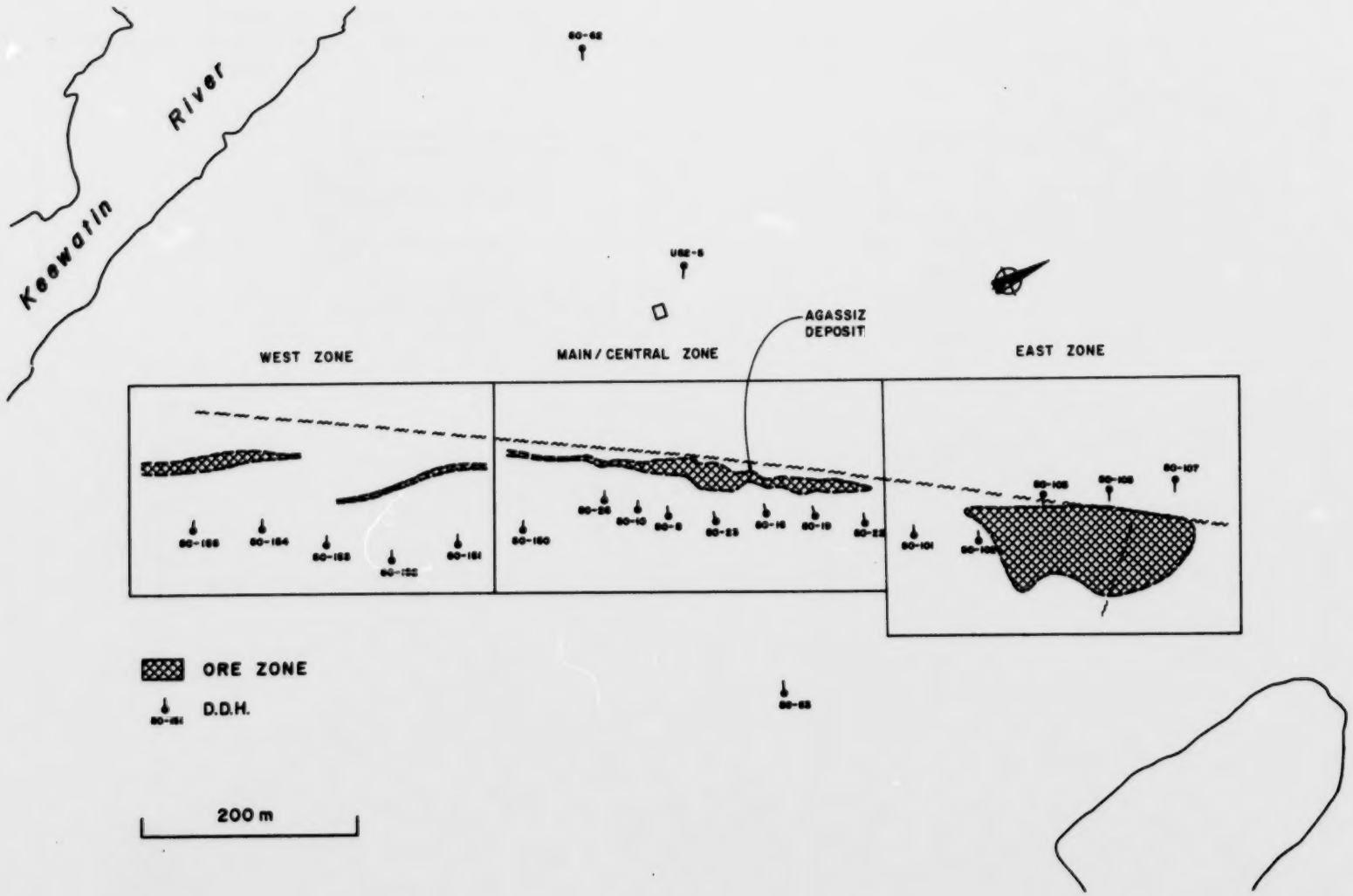

Figure 8: Locations for diamond drill holes that were logged and sampled during this study and their relationship to the subdivisions of the Agassiz deposit.

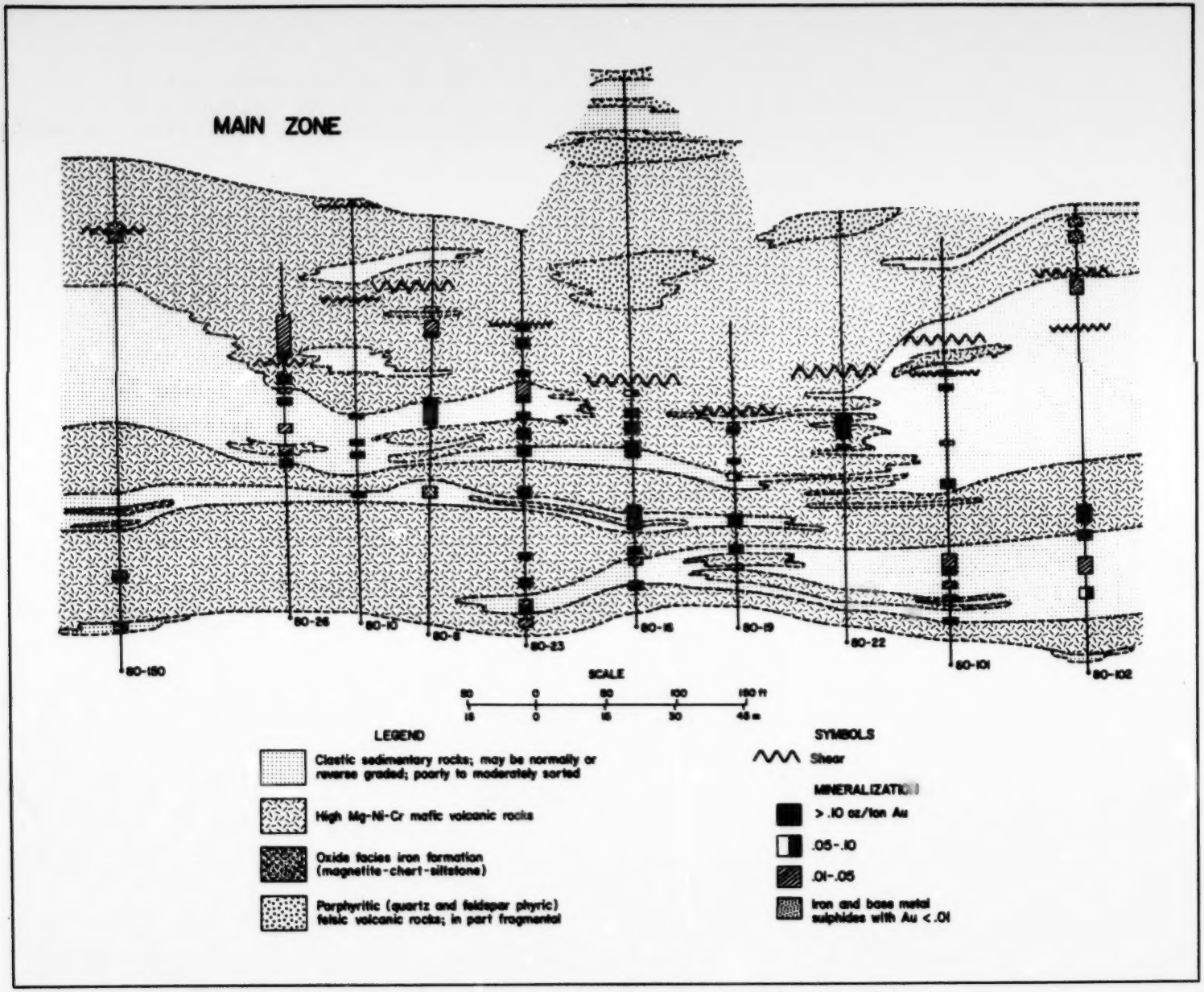

Figure 9: Simplified geology and mineralized zones in the Agassiz deposit Main Zone.

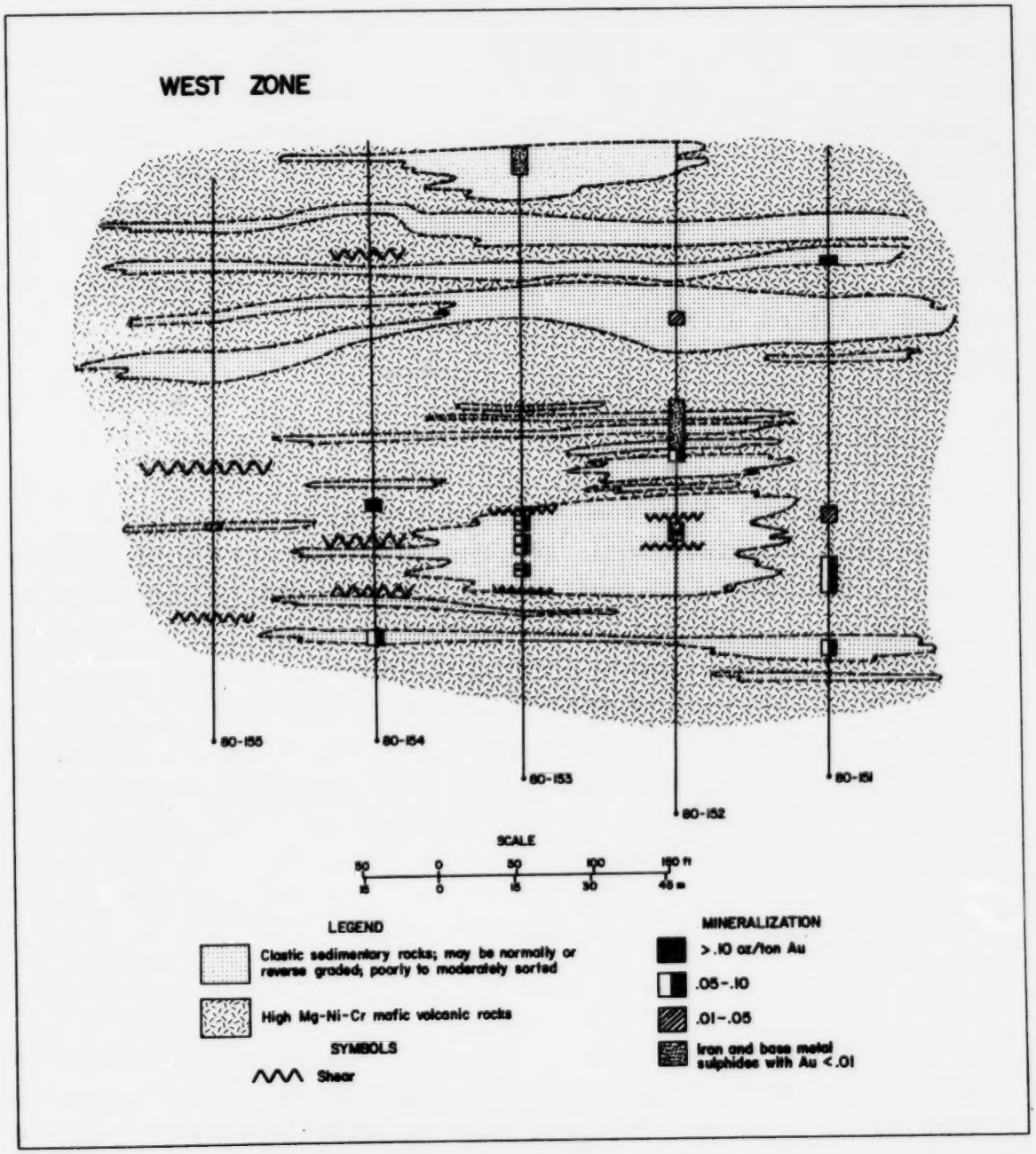

Figure 10. Simplified geology and mineralized zones in the Agassiz deposit West Zone.

and carbonatization, respectively, is persistent. Generally, 10% or less disseminated sulphides are present in the rocks of this zone; however, 2 - 3 cm intervals of near solid iron sulphides and short intervals of 25% iron sulphides are present. An occurrence of visible gold has been observed in association with 15% disseminated arsenopyrite, pyrrhotite, pyrite and galena in convoluted, tightly folded siltstone interlayered with high Mg-Ni-Cr basalt. Sheared rocks (North Shear?) have been recognized in diamond drill core from this area; however, only trace amounts of gold have been observed in association with the sheared stratigraphy.

(3) East Zone

In the East Zone (Fig. 11) heavily disseminated (30 - 40%) iron sulphides with arsenopyrite, sphalerite and galena occur in tightly folded conformable lenses accompanied by locally intense carbonatization. Deformed carbonate-quartz-sulphide veins are present throughout the East Zone and contain arsenopyrite, sphalerite and galena in addition to iron sulphides. Gold mineralization is associated with the most abundant sphalerite and galena observed in the deposit. This association is illustrated by selected 1.5 m assay results that give the following range:

Au (g/tonne)	Ag (g/tonne)	Pb(%)	Zn(%)
12.4 - 31.1	163.3 - 272.2	2.80 - 4.50	4.50 - 6.50

The abundance of Pb and Zn in the East Zone with respect to the Central and West Zones represents the only known metal zonation recognized to date. Gold may also be associated with sulphide facies iron formation in this zone with 3.4 g/tonne Au and 27.0 g/tonne Ag documented in a sheared banded pyrite layer.

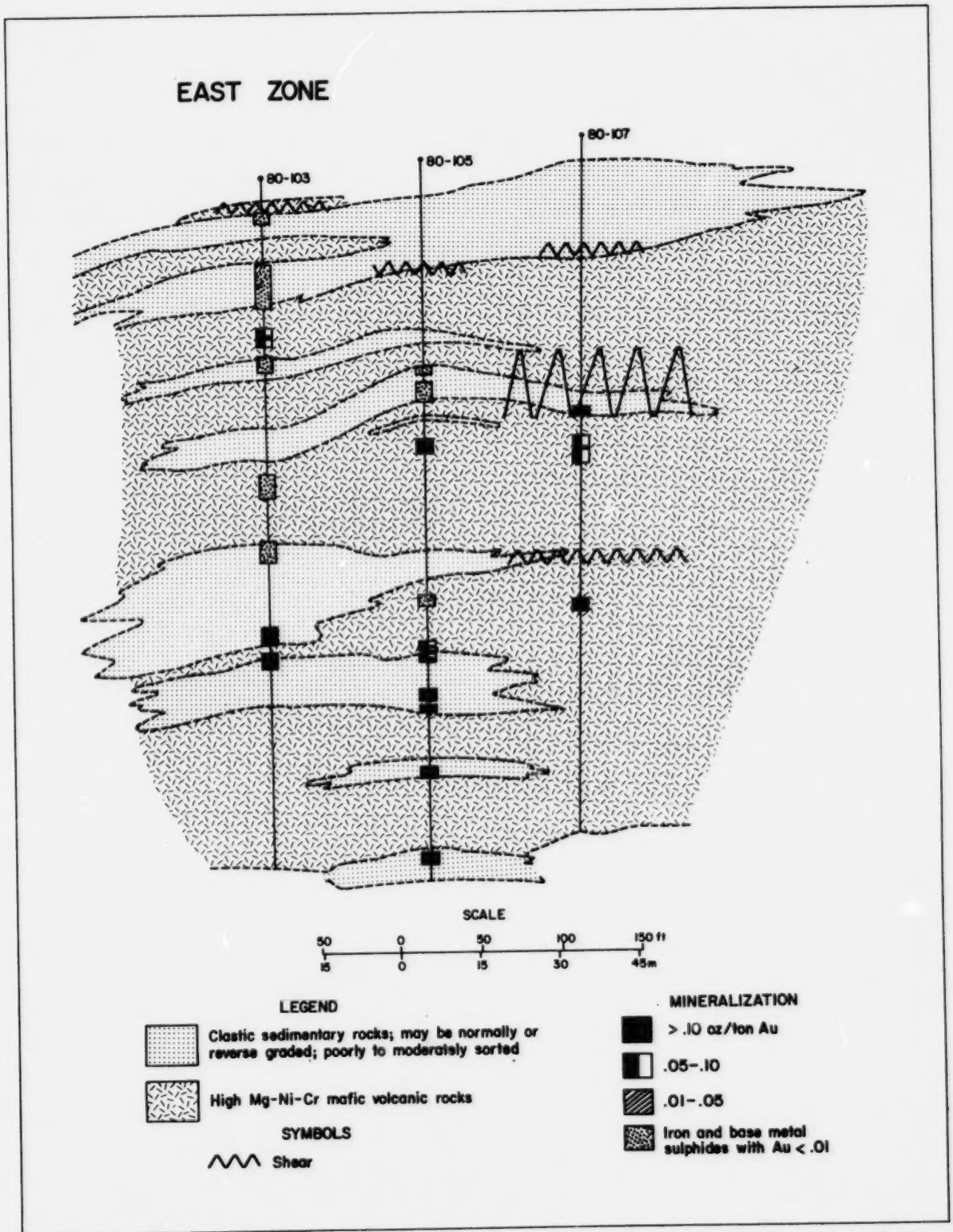

Figure 11. Simplified geology and mineralized zones in the Agassiz deposit East Zone.

Stratigraphically, the Agassiz mineralization is interpreted to originally have been confined to a restricted, narrow stratigraphic interval; however, deformation and subsequent transposition have produced discrete mineralized zones that appear to occur at different stratigraphic levels. This concept is discussed in more detail under the section dealing with deformation and mineralization.

DEFORMATION AND MINERALIZATION

Geological observations from diamond drill core and examination of polished rock slabs collected from the dumps at the Agassiz deposit indicate that the host rocks and mineralization have been affected by a complex sequence of deformational events. The thinly bedded, sulphidic and altered character of the interlayered siltstones and high Mg-Ni-Cr basalt flows and tuffs has effectively focussed the deformation on the mineralized zone of the deposit. The overlying rocks to the Agassiz Metallotect contain slightly elongate fragments and the underlying basaltic rocks are characterized by a weak to moderate foliation. Both of these units are relatively undeformed when compared to rocks in the mineralized zone.

Mineralized Zone

The carbonatized, biotite-rich siltstone units in the mineralized zone are characterized by a well developed foliation that is parallel or at a low angle to primary bedding. Elongate 1 x 5 cm carbonate-quartz laminae, marked by relict fold hinges and incipient boudinage structures, are present in these units. The carbonate-quartz laminae are aligned parallel to the foliation in the rock (Fig. 12). These laminae impart a fragmental appearance to the rock; however, the laminae are interpreted to represent an earlier vein set that has been rotated into the plane of the foliation and subsequently transposed. This same vein set is present in the chert-magnetite oxide facies iron formation that occurs interlayered with the siltstone in the mineralized zone; however, owing to the greater competency of the chert-magnetite layers relative to the altered, sulphidic, biotite siltstone the iron formation and the carbonate-quartz vein set remain relatively undeformed (Fig. 13). Recrystallized, folded and transposed sulphide laminae are also present in the

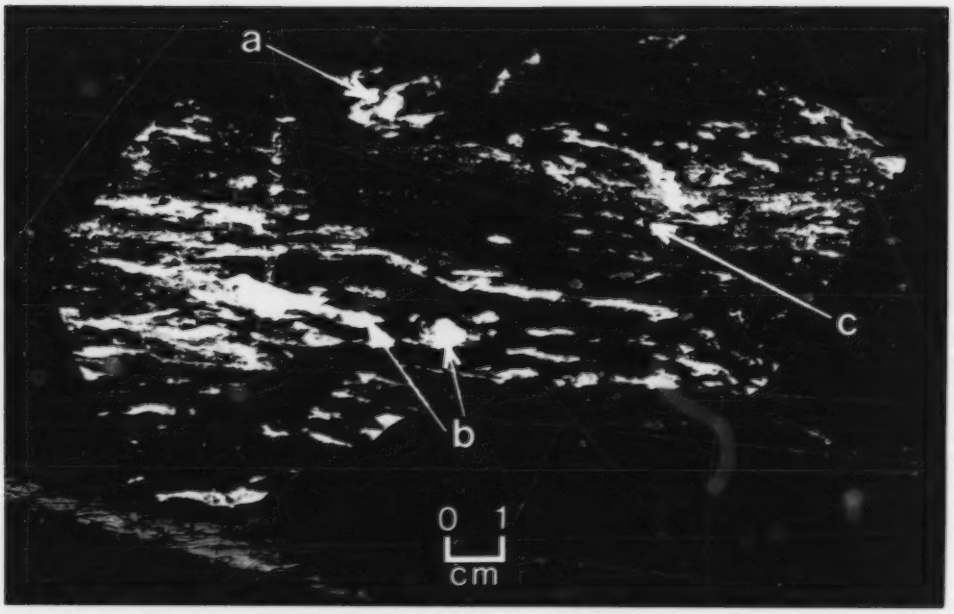

Figure 12: Quartz-carbonate laminae (deformed quartz-carbonate veins) in mineralized biotite siltstone, Agassiz deposit. Note: a - tightly folded quartz-carbonate laminae; b - boudinaged quartz-carbonate laminae; c - disseminated pyrite, ± arsenopyrite, sphalerite, galena, chalcopyrite.

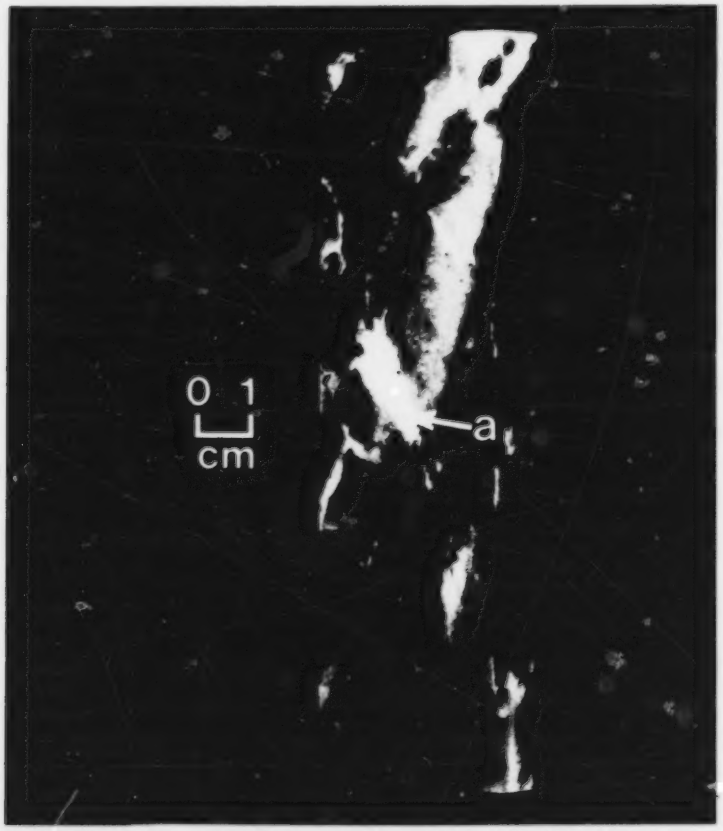

Figure 13: Undeformed quartz-carbonate vein in magnetite-chert banded iron formation, Agassiz deposit.

carbonatized biotite-siltstone. A finely disseminated silvery sulphide mineral, tentatively identified by X-ray powder diffractograms as geocronite ($Pb_{27}Sb_8As_4S_{45}$) has been observed in the pressure shadow of the hinges of the carbonate-quartz laminae. The thinly bedded, high Mg-Ni-Cr basaltic rocks interlayered with the siltstones may be characterized by a well developed foliation with a lineation defined by the alignment of the long axes of amphibole (actinolite, hornblende) minerals. Tightly folded magnetite-chert oxide facies iron formation is observed within the fine grained chlorite-rich high Mg-Ni-Cr layers as well as folded and boudinaged white carbonate stringers. The end result of this folding and deformation of the host rocks is reflected in a geological cross-section, constructed from diamond drill core, indicating the absence of any single recognizable marker bed that can be correlated between diamond drill holes over distances greater than 25 m (Fig. 9, 10, 11).

Discussion

The original nature of the deposition of mineralization at the Agassiz deposit is difficult to ascertain; however, the association of base and precious metal mineralization including iron sulphides with normal and reverse graded siltstone, oxide, sulphide and silicate facies iron formation and high Mg-Ni-Cr mafic flows/tuff indicates a close affinity to clastic and chemical sedimentation. Multiple deformation of the host rocks and mineralization has resulted in the mobilization of originally syngenetically deposited sulphide and gold and silver into sulphidic, gold-silver bearing quartz veins, discordant sulphide-rich laminae (probably as fracture infillings) and diffuse mineralized zones. Mobilization of pre-existing mineralization accompanied a post-depositional increase in the bulk permeability of the host rocks. This increase in host rock permeability resulted

from the development of structural anisotropies such as the well developed foliation in the mineralized zone host rocks and the later fracture zones that were subsequently filled with carbonate, quartz and auriferous sulphide minerals. The formation of uni- or multi-directional vein sets accompanied by zones of disseminated mineralization, such as those observed at the Agassiz deposit have probably resulted from variations in stress and strain rates, temperature, pressure and the altered nature of the host rocks to the mineralized zone.

The induced permeability in the mineralized zone host rocks is interpreted to have resulted from an episode of intra-formational folding followed by brittle and ductile deformational events. The thinly bedded, interlayered, altered and sulphidic nature of the host rocks represent units of highly variable ductility and would tend to focus zones of tension and compression during a folding event. Tightly folded oxide facies iron formation in the high Mg-Ni-Cr tuffs (Fig. 14) represents an example of the tight intra-formational folding episode that has affected the host rocks of the mineralized zone. The zones of tension and compression developed in the host rocks resulted in the development of tension fractures.

Rock units adjacent to the mineralized zone, such as the overlying aluminous basalts or even the chert-magnetite oxide facies iron formation within the mineralized zone, are characterized by drastically different physical properties. As a result these units will also reflect variable degrees of deformation and development of tension fractures which will represent the locus of focussed fluid flow. This brittle deformational event subsequent to the folding event resulted in the development of tension fracture systems in the mineralized zones. A second deformation in the deposit is related to a ductile deformational event during which a further increase in permeability was induced by the development of penetrative

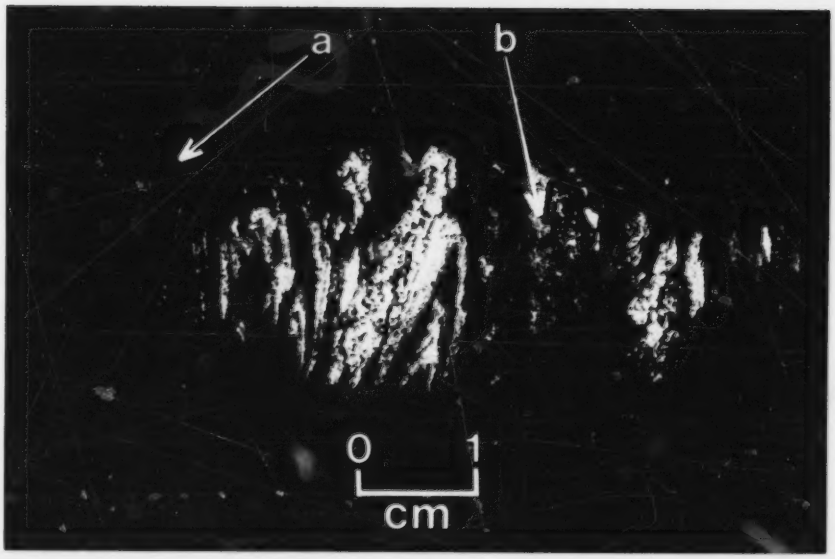

Figure 14: Tightly folded oxide facies (magnetite-chert) banded iron formation in a fine grained "picrite" layer, Agassiz deposit. Note: a - oxide facies iron formation; b - fine-grained picrite with 1 - 2% disseminated pyrrhotite.

fabrics and intergranular pore space accompanying recrystallization. Mobilized sulphide mineralization would then be channelled through and along the rock fabrics and result in widespread disseminated mineralization and diffuse alteration zones. The ductile deformation, therefore, is viewed as a method for boudinage and transposition of the carbonate-quartz-sulphide vein set that resulted from the earlier brittle deformation as well as the mobilization of auriferous sulphide mineralization into diffuse mineralized zones. The thinly bedded host rocks to the mineralized zone that were initially folded and overprinted with a brittle deformation would be transposed as a result of this ductile deformation ultimately producing the podiform or lobate stratigraphy that characterizes the cross-sections in Figures 9, 10 and 11. In part, sulphide minerals such as galena, sphalerite and arsenopyrite may have been incorporated into the pore spaces in the siltstone units during diagenesis (filter pressing?) and then mobilized into dilatant zones during deformation.

GENESIS OF THE DEPOSIT

Introduction

The tholeiitic basalts (Fox and Johnson, 1981) that characterize the footwall to the Agassiz deposit and the interlayered clastic and chemical sedimentary rocks and high Mg-Ni-Cr basaltic flows and tuffs in the Agassiz mineralized zone represent a marked compositional change in the nature of the products of Wasekwan volcanism in the northern belt of the Lynn Lake greenstone belt. The Agassiz stratigraphic sequence is situated between thicker sequences of fragmental aluminous (greater than 18% Al_2O_3) basalt and mafic, polymictic debris flows and as such represents a unique volcanic and sedimentary environment into which exhalative brines were deposited.

The geological characteristics of the Agassiz mineralized zone as it was originally deposited are consistent with an exhalative mechanism for the genesis of the mineralization. The association of base and precious metal mineralization with products of clastic and chemical sedimentation represents an overlap between the two distinct geological and depositional environments. Subsequent deformation has resulted in mobilization (lateral secretion) and re-siting of some of the mineralization as fracture-fillings, veins and accompanying zones of diffuse mineralization and alteration.

The development of the various styles of mineralization in the Agassiz deposit are discussed in light of the nature of the original depositional environment, subsequent deformation and then compared and contrasted with recent ideas concerning gold deposit genesis.

General Model

A general model for the evolution of an exhalative mineral deposit requires the percolation of seawater (Spooner, 1977) or a mixture of seawater and connate water (Hodgson and Lydon, 1977) downward into the crust along fractures and/or faults. A mixture of these waters with waters of magmatic derivation (Ohmoto and Rye, 1974; Hattori and Muehlenbachs, 1980) during their descent into the crust should not be precluded (Franklin et al., 1981; Gale, 1983). These fluids increase in temperature with depth and subsequently react with the country rocks producing a shift in the fluid composition to one of a reduced or neutral character with high concentrations of chlorine, alkali elements and silica (Bischoff and Dickson, 1975). Continued reaction with the country rocks and/or mixing with metal-charged magmatic waters produces a fluid characterized by high metal content which is then convected to the surface along plumbing systems comprising zones of high initial or induced permeability. The development of these convective currents responsible for driving the fluids upwards through the crust has been related to (i) oceanic crustal heat flow regimes, particularly above actively spreading ridges, and (ii) local extrusive-intrusive events (Franklin et al., 1981). The metalliferous fluids are subsequently debouched onto the seafloor and through mixing of the brine with cooler, alkaline and oxidizing seawater precipitation of sulphide, oxide and silicate minerals occurs. The nature or shape of the resulting deposit is dependent to a large degree on seafloor topography, sedimentation rates and water depth. The metal-charged brine may flow down-slope and pond in a topographic depression(s) or it may spread out along the seafloor to produce a relatively thin, uniform layer of exhalative precipitate. In either of the above two scenarios the bulk of the mineralization will be distal to the original site of fluid-brine venting. Alternatively, the distribution of the exhaled brines and the precipitation of exhalative products may be restricted due to

the localization of the vent in a basin or other topographic depression. Under these circumstances the resultant mineralization will be proximal to the exhalative vent and will therefore be associated with a "feeder" or alteration pipe(s).

A detailed mechanism for the development of an exhalative-type gold deposit has been described by Keays (1982). The concept of "rare and special source rocks" was invoked to explain the source of Ni and Au at a number of deposits in Australia and Africa. The source rock concept is not an original one as Boyle (1961), Viljoen et al. (1970) and Pyke (1975) considered certain mafic and ultramafic rocks to be the source of Au for a number of gold deposits. The development of these ideas may be related, in part, to the work of Shcherbakov and Perezhogin (1963) who determined that mafic and ultramafic rocks were characterized by inherently higher gold contents than intermediate or felsic rocks. This concept was questioned by Anhaeusser et al. (1975) who found in a study of komatiitic rocks from the Barberton greenstone belt, that gold concentrations were not anomalous in these rock types and thereby questioned whether ultramafic rocks in general were gold enriched. In a study designed to determine whether or not the contribution of gold to a hydrothermal system by ultramafic rocks was controlled by the mineralogical siting of this element, Keays and Scott (1976) examined the gold contents of ocean ridge pillow basalts. It was determined that the glassy rims of the pillows contained significantly more gold than the pillow interiors. This variation was attributed to Au and S mobilization during rock-seawater interaction soon after pillow formation and the re-siting of gold in the glassy pillow rims. The gold is accessible to gold deposit formation since the glassy pillow rims can be leached during rock-seawater interaction. The variability of the gold content in the glassy pillow rims was found to be significant, based on rock type. Gold varied from 0 ppb in most basaltic rocks to 6 - 8 ppb in high-Mg basalts and komatiites and further substantiates the

need for a particular or special lithology to serve as a source rock for Au. Keays and Scott (1976) found that the Au content in pillow interiors correlated with MgO, Ni and Cr thereby indicating that Au is bound to silicate and oxide minerals and is therefore relatively inaccessible to rock-seawater interaction and gold deposit formation. In order to prevent loss or dilution of the accessible gold following rock-seawater interaction due to the debouching of these Au-enriched fluids onto the seafloor, chemical interflow sediments, including organic and sulphidic types, are available to trap the liberated gold. Interflow sediments of this type are represented by those at Kambalda, Western Australia, and have been found to contain as much as 150 ppb Au. The reaction between pyrite and organic carbon or methane in these sediments would produce H_2 and CO_2, essential compounds in the formation of gold deposits. Keays (1982) summarizes this source rock hypothesis by suggesting an enhanced gold content for komatiitic or related magmas and relates this to the high temperature of magma generation and subsequent saturation of the magma with respect to immiscible sulphide liquids. Magma differentiation would produce an immiscible sulphide fraction that would effectively scavenge Au and other chalcophile elements due to high partition coefficients. These rocks containing Au-enriched and easily digested or leached sulphides would then become sources for accessible gold during rock-seawater interaction.

Genesis of the Agassiz Deposit

The genesis of the Agassiz gold-silver deposit is difficult to ascertain owing to the multiply deformed nature of the host rocks. There are, however, numerous valid observations and extrapolations based primarily on diamond drill core logging and supplemented by thin section studies and geochemistry, that can be used to propose an origin for the

deposit. The development of the mineralization may have proceeded as follows:

1. Extrusive high Mg-Ni-Cr volcanic rocks deposited upon a basal substrate of aluminous fragmental basalt.

2. Subsequent to flow deposition interflow clastic and chemical sediments were deposited on the high Mg-Ni-Cr flows. Chemical sediments (sulphidic) acted as traps for accessible gold and nickel liberated from (1) the high Mg-Ni-Cr units by interaction with seawater and (2) leaching of precious metal (Au) enriched sulphide immiscible blebs. Gold was probably transported in the exhaled brines as a chloride complex along with the base metal components and in part as a sulphur-based (HS) compound accompanying the iron sulphides.

3. The reaction of the iron sulphides with organic carbon produced H_2O and CO_2 resulting in carbonatization of the volcanic units associated with the gold-enriched sulphides.

4. Repetition of this scenario continued until the waning of sulphidic exhalative activity resulted in the absence of a chemical trap for the liberated accessible gold. This resulted in the dilution of the gold in seawater.

5. The extrusive high Mg-Ni-Cr volcanic event is capped by aluminous, fragmental basalt and mafic debris flows marking the end of deposition of rocks of the Agassiz Metallotect. Sulphide zones developed outside of the Metallotect are not characterized by important gold-enriched clastic and chemical sedimentary rocks owing to the lack of a suitable source rock and style of deformation.

6. Intraformational folding and accompanying brittle deformation is focussed on the thinly bedded, sulphidic mineralized zone of the deposit. This deformation produces

tightly folded stratigraphy and zones of tension and compression resulting in the development of dilatant zones that are infilled by lateral secretion with gold-enriched iron and base metal sulphides, carbonate and quartz.

7. Ductile deformation of the host rocks produces transposed stratigraphy and diffuse zones of alteration and mineralization. Ultimately a lensoid, podiform or lobate stratigraphy, including the mineralized zones, results from these deformational events.

8. Late brittle failure produced a discordant series of sulphide-filled fractures which crosscut the rock fabric induced by the ductile deformational event.

Discussion

The application of this series of geological events explains a number of geological observations of the deposit. The absence of an "alteration-pipe" in the footwall rocks is perhaps the most important point to be considered if one is proposing exhalative activity for the origin of the Agassiz mineralization. The absence of an alteration pipe at the deposit may be explained by: 1) failure to recognize chemical or mineralogical patterns in the rocks produced by the development of an exhalative plumbing system; or 2) the depositional site of the Agassiz deposit does not represent the original site of brine venting, i.e., the deposit is distal to the exhalative vent or the deposit has been tectonically displaced from the vent. Diamond drill holes logged and sampled on 25 m centres along the known strike length of the Agassiz deposit did not reveal a mineralogical or chemical expression of an alteration pipe.

Metamorphic dewatering of rocks in the area of the Agassiz deposit with the host rocks to the mineralization focussing the Au-enriched metamorphic fluids (along the lines of an aquifer) could result in a Au deposit with distal affinities. The relatively thin sequence of favourable host rock types as well as the presence of auriferous sulphide facies iron formation interlayered with normally and reverse graded siltstones (suggesting primary depositional modes) would tend to negate the metamorphic degassing-aquifer mechanism as the sole possible explanation for the genesis of the deposit. This would suggest a possible three-fold emplacement of the mineralization as it is recognized in this study:

1) deposition of auriferous iron and base metal sulphides as exhalites distal to the vent(s) during periods of clastic and/or no sedimentation;

2) scavenging of gold and possibly nickel and chrome from solutions produced during the reaction between seawater and volcanic rocks by sulphidic chemical sediments to give a gold-enriched sulphide deposit;

3a) mobilization of the gold-enriched sulphide and carbonate and quartz into dilatant zones accompanying deformation; or

3b) introduction of a second, totally epigenetic mineralizing event producing the auriferous carbonate-quartz-sulphide veins (both 3a and 3b in response to a deformational event).

Rather than invoking a discrete mineralizing event to explain the crosscutting auriferous carbonate-quartz-sulphide veins the more plausible explanation would seem to be the former, i.e., mobilization of previously syngenetically deposited gold-bearing sulphides. This concept has been

invoked to explain apparently co-existing syngenetic and epigenetic styles of mineralization in massive sulphide deposits (Lawrence, 1975) and perhaps in a more relevant study by Zakrzewski and Nugteren (1984) in a study of the distal-type Hallefors silver deposit in Sweden. In that study diagenetic and metamorphic processes were considered to be responsible for the mobilization of ore-forming elements into vein sets, faults and bedding joints. The authors noted that outside the mineralized zone vein systems were either absent or poorly developed and less extensive. They concluded that the veins represented mobilized ore material from the ore "horizon" and the distance of mobilization was equivalent to the maximum length of the veins, i.e., a few hundred metres. Although the vein sets developed during brittle deformation of the Agassiz stratigraphy have been transposed, a process whereby the mobilization of syngenetically deposited gold-enriched sulphides into fractures is favoured. Base and precious metals sited in the pore spaces of the clastic sedimentary rocks during diagenesis (filter pressing?) may also have contributed to these late auriferous veins by "sweating out" their metals in response to deformational events.

Although the observed podiform or lobate stratigraphy in the deposit could be representative of a primary depositional mode of either the clastic sedimentary rocks or the Mg-Ni-Cr-rich volcanic units the observed structural characteristics (hinges, boudinage) tend to support a deformational origin. Furthermore, a syngenetic, exhalative theory for the origin of the deposit is supported by the identification of stratiform solid sulphide layers in association with iron formation in the Agassiz stratigraphy at numerous locations along the Agassiz Metallotect.

Analogs

The stratigraphic characteristics of the sequence of rocks hosting the Agassiz Au-Ag deposit and the nature of Agassiz mineralization are not unique in Archean or Proterozoic terranes. Numerous examples of gold deposits hosted within mafic/ultramafic rocks or in interlayered clastic sedimentary rocks and mafic/ultramafic volcanic rocks have been documented in the literature. Pyke (1975) describes the spatial association between ultramafic metavolcanic rocks and gold deposits of the Timmins area and proposed that these ultramafic rocks were the source for the gold. Although the "source bed" concept has been discussed at considerable length in the literature (Meyer and Saager, 1985) it is the spatial association of interlayered iron formation and high Mg-Ni-Cr mafic/ultramafic rocks that is particularly significant with respect to the Agassiz deposit. In a recent publication Foster (1982) presents a detailed geological, geochemical and ore genesis summary of numerous gold deposits worldwide. Although many of the examples of gold deposits described in this text are of Archean age most of the "iron formation-mafic/ultramafic" associated deposits have geological characteristics similar to those of the Proterozoic Agassiz deposit. The spatial associations and the overall characteristics of these deposits will be described briefly before comparisons are drawn between Proterozoic and Archean gold deposits and the Agassiz deposit.

Foster and Wilson (1982) review the gold deposits of Zimbabwe and identify the major types as stratabound orebodies in banded iron formations and volcaniclastic rocks and vein and shear-zone type deposits. The iron formations are commonly intercalated with mafic and ultramafic volcanic rocks and clastic sedimentary rocks and this scenario represents the most important source of gold. Genetically, the authors suggest that magmatic and metamorphic mobilization of gold (i.e.

lateral secretion) from the iron formations were responsible for vein-type gold deposits within the same host rock unit as the stratabound deposits. Overall, approximately 154 tonnes of gold have been produced from 130 deposits hosted within these "iron-formation" related deposits. Primary anomalous concentrations of gold occur within these iron formations; however, economically feasible gold deposits appear to be the result of subsequent tectonic and hydrothermal processes. It has not been established whether the gold in the oreshoots was derived solely from the iron formation or an external source. One of the Zimbabwean deposits has been described in detail by Fabiani (1982). The Archean Athens gold deposit (Mvuma, Zimbabwe) contains chalcopyrite, pyrite and pyrrhotite with gold and minor Bi, Zn, Pb, Co and As in chloritic-tremolitic-talcose schists interpreted to represent altered mafic and ultramafic volcanic rocks. Mineralization appears to be related to an early epigenetic style of mineralization followed by mobilization and redeposition of the auriferous sulphides in dilatant zones. Although banded iron formations are absent from this geological environment the association of gold ore with mafic-ultramafic rocks is apparent.

The New Consort gold deposit in the Archean Barberton greenstone belt demonstrates the spatial relationship of komatiitic rocks to gold mineralization. Viljoen (1982) discusses the gold mineralization within the 4 m thick Consort Bar, a fine grained, variably coloured (black, green, brown), well laminated (1 - 5 mm thick) cherty rock that characterizes the New Consort deposit. The mineralization comprises interlayered sulphide-rich bands (arsenopyrite and pyrrhotite) within the Consort Bar; however, gold mineralization is also located within auriferous sulphide blebs in amphibolites that underlie the Consort Bar. The amphibolites may have supplied gold to the Consort Bar as a result of the leaching of these rocks by interaction with seawater or waters of metamorphic derivation.

Examples of Canadian Proterozoic gold deposits with geological characteristics similar to those of the Archean are less abundant. This is probably related to the fact that the bulk of exploration and development of gold deposits has been in Archean terrane and this is reflected in the subsequent data base. Van Straaten (1982) presents an overview of gold deposits in Tanzania. The Lupa goldfield (SW Tanzania) represents a Proterozoic gold camp with a long history of gold production. Since 1935 approximately 600 000 oz. of gold have been produced from deposits, in part, associated with banded ferruginous or magnetite-bearing quartzite interlayered with anthophyllite-grunerite amphibolite.

In each of the above mentioned deposits the association of gold with mafic and ultramafic rocks is apparent. Perhaps of more importance with respect to a comparison with the Agassiz deposit is the presence of banded iron formations interlayered with these mafic/ultramafic rock units.

A detailed study by Hallager (1982) concerning an Archean gold deposit near Jardine, Montana, provides an opportunity to compare the geological characteristics of that deposit with those of Agassiz. The Jardine deposit has an early history of production (4403 kg Au; 347 000 kg W; 5 722 000 kg of As to 1943) with the initial discovery of the deposit attributed to placer mining and subsequent prospecting in the immediate area. The Jardine deposit is characterized by the preferential concentration of Au, As and W within interlayered banded iron formation and fine grained carbonaceous, detrital sedimentary rocks. The gold-bearing iron formations occur within a sequence of quartzites and quartz-mica schists. This stratigraphic sequence can be traced using airborne magnetic techniques; a pre-folding 100 km^2 extent for the iron formation has been proposed. The bulk of the Au and As in the deposit is hosted within sulphide facies

iron formation which consists of massive to finely laminated arsenopyrite, pyrrhotite, chlorite and quartz. Lesser components are hornblende, grunerite, galena, sphalerite, chalcopyrite and scheelite. Arsenopyrite also occurs as coarse euhedral crystals and finely disseminated grains in a chlorite or biotite schist matrix. Layers of amphibole-chlorite-quartz high in Mg, Ni and Cr are interbedded with these rocks. The sulphide facies iron formation interdigitates with and, in part, is enveloped by a graphitic quartz-biotite schist. The biotite schist contains between 1.6% and 6.4% non-carbonate carbon. The biotite schist grades laterally into garnetiferous (almandine) chlorite schists.

The auriferous sulphide facies iron formation is considered to be a chemical precipitate that concentrated during periods of basin starvation and was diluted with clastic detritus during periods of active sedimentation. Clastic material was derived from a plagioclase+quartz-rich terrane with local reworking. Thin muscovite schist layers in the stratigraphy may represent distal ash deposits and the high Mg-Ni-Cr layers interbanded with the sulphide facies iron formation are considered to represent the products of ultramafic volcanic activity coincident with iron formation deposition.

The similarities between certain geological characteristics of the Jardine and the Agassiz gold deposits based on the above description are apparent. Both deposits are marked by the presence of interlaminated, graded clastic sedimentary rocks, sulphide and oxide facies iron formation and high Mg-Ni-Cr mafic/ultramafic layers. The bulk of the Au and As mineralization is confined to the sulphide facies iron formation at Jardine and although this relationship is not implicit at Agassiz a reconstruction of the Agassiz mineralizing event would indicate a similar gold siting. Both deposits occur within stratigraphic sequences that are

extensive in an areal and lateral sense with some degree of reworking. Both deposits require a felsic terrane in order to derive the clastic and detrital sedimentary rocks which characterize the stratigraphy. Although exact stratigraphic relationships between the Agassiz stratigraphy and other rocks in the northern belt of the Lynn Lake greenstone belt are uncertain the Lynn Lake Rhyolitic Complex to the west may have supplied feldspar and quartz-rich detritus to produce the siltstones within the Agassiz stratigraphy. Further evidence to support the possible link between the Agassiz stratigraphy and the Lynn Lake Rhyolitic Complex to the west may be the zinc-rich nature of parts of the Agassiz mineralization and the zinc-rich massive sulphide deposits, such as the Nicoba, Y and Frances Lake zones (Fedikow and Gale, 1982), that occur within the Rhyolitic Complex. Basic differences between the Agassiz and Jardine deposits would include the absence of W, the lack of a thick sedimentary pile and, apparently, carbonate facies iron formation at the Agassiz deposit. Both deposits contain base metal sulphides (Pb,Zn) and are marked by a wide range of primary trace element dispersion patterns. Although non-carbonate carbon analyses for the Agassiz rocks are not available at the time of writing the occurrence of graphitic layers within Agassiz stratigraphy east of the deposit have been documented by exploration companies working in the area.

The two deposits are marked by basic similarities and some differences. The over-riding consideration, however, must be the fact that each deposit is stratabound and comprises auriferous sulphide facies iron formation interlayered with high Mg-Ni-Cr ultramafic layers. Finally, from an exploration point of view these basic characteristics can be observed areally for 100 km^2 in the case of the Jardine deposit and laterally over a 65 km strike length in terms of the Agassiz deposit.

The Agassiz Au-Ag deposit would seem to compare favourably within the theme and variation of both Proterozoic and Archean stratabound gold deposits. Comparisons with world class gold deposits (Archean: Lupin, N.W.T., Canada; Proterozoic: Homestake, Lead, U.S.A.) may be drawn on the basis of gross stratigraphic relationships (including the presence of iron formation, style of mineralization and ore genesis) in order to formulate exploration concepts that may be applied on a grass roots basis. The realization of basic similarities between the stratigraphy within the Agassiz Metallotect and other stratigraphy of regional extent known to contain past and presently producing gold occurrences is a first step towards practical and progressive exploration of 65 km of potential gold-bearing stratigraphy.

GEOPHYSICAL SIGNATURE OF THE AGASSIZ METALLOTECT

The Agassiz stratigraphic succession has been traced for a distance of approximately 65 km by geological mapping, diamond drilling and through a compilation of information from cancelled assessment files submitted by exploration companies working in the Lynn Lake greenstone belt. This stratigraphy can be delineated by a variety of regional and detailed geophysical surveys. The Agassiz deposit is located on the flank of an airborne Input anomaly (Questor, 1976). This anomaly is not restricted to the immediate area of the deposit but can be traced through Minton Lake, north of Arbour Lake, through Muskeg and Farley Lakes and southeast to the south shore of Barrington Lake (Fig. 15). This zone of coincident electromagnetic and magnetic anomalies can be attributed to the presence of the high Mg-Ni-Cr basaltic rock units interlayered with sulphidic siltstones containing magnetite-chert oxide facies iron formation that characterize not only the Metallotect but also the mineralized zone of the Agassiz deposit. Recent vertical field gradiometric surveys undertaken by the Geological Survey of Canada (see GSC Open File Reports 889 and 1074) confirm the presence of this geophysically distinctive stratigraphy over the proposed 65 km strike length. IP surveys have been most effective in delineating the Agassiz mineralized zone (Fig. 16) and this method is routinely applied to the search for repetitions of Agassiz-type mineralization within this metallotect.

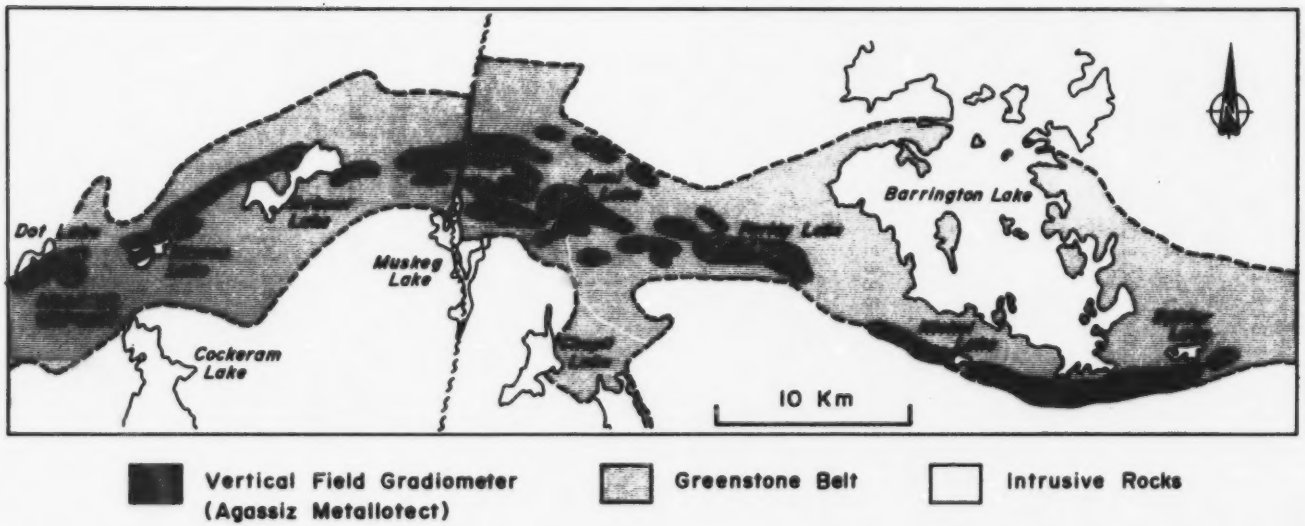

Figure 15: Airborne Input (Questor, 1976) and gradiometric signature of the Agassiz Metallotect.

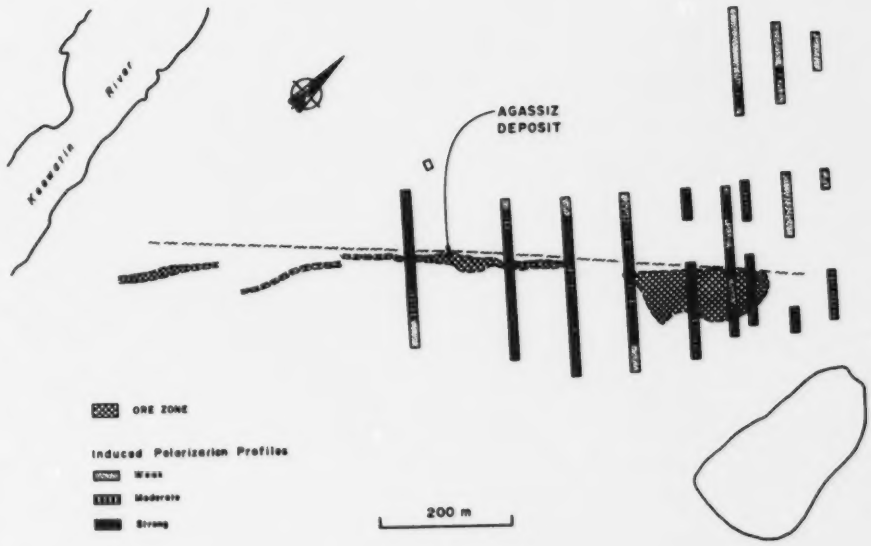

Figure 16. Ionization potential profiles over the Agassiz Au-Ag deposit.

EXPLORATION RECOMMENDATIONS

A discrete stratigraphic sequence with a characteristic response to regional airborne geophysical surveys (Input, vertical gradiometer) and detailed ground geophysics (IP) has been recognized over a strike length of approximately 65 km. Within this sequence of rocks known gold mineralization occurs as originally syngenetically deposited gold-enriched sulphides later reconstituted into a combination of both the former as well as crosscutting carbonate-quartz-sulphide vein sets and diffuse zones of disseminated mineralization. Historically, the region over which this Metallotect is developed is characterized by a paucity of outcrop and a preponderance of till and peat bog cover. Exploration for repetitions of Agassiz-type gold mineralization must therefore be fully integrated utilizing geological, geophysical and geochemical methods whenever possible.

Geology

The presence of interlayered clastic and chemical sedimentary rocks and the high Mg-Ni-Cr basaltic units is indicative of a highly prospective gold environment. Tightly folded and/or faulted stratigraphy accompanied by carbonate ± quartz (veins, patches, flecks) is considered to represent prerequisites for the development of gold mineralization in other than background concentrations. The source bed concept invoked for the genesis of the Agassiz mineralization requires the high Mg-Ni-Cr basaltic units (locally referred to as picrites) within the stratigraphy of the Metallotect.

Geophysics

The deformational overprinting of the Agassiz mineralization indicates that offsets of geophysical responses within the Metallotect could represent faulting and other deformational scenarios similar to those at the Agassiz deposit. Coincident ionization potential anomalies would constitute exploration targets worthy of more detailed investigations, i.e., diamond drilling.

Geochemistry

The host rocks to the Agassiz deposit are characterized by the development of a large suite of primary dispersion trace element halos that are easily delineated using standard analytical methods (AAS: INAA) (Fedikow, in prep.). This feature can be used in an outcrop sampling program owing to the vertical, lateral and downdip extensions of these anomalous concentrations of trace element halos about the Agassiz mineralization. Rock geochemical methods would find a similar use during the evaluation of diamond drilling programs. The primary geochemistry of the high Mg-Ni-Cr basalts ("picrites") is distinctive and these rocks, considered to be, in part, source beds for the Agassiz mineralization, can be geochemically fingerprinted with a straightforward Mg-Ni-Cr analysis. In the absence of outcrop or diamond drill core, humus and/or vegetation geochemistry can provide useful information for property-scale evaluation. Since the high Mg-Ni-Cr basalts are soft, recessive rock units, they are more often than not located within or beneath swampy, low-lying areas. Peat bog geochemical surveys appear to represent a potentially useful tool for a regional or local evaluation of gold potential within the Metallotect. To date, the most successful geochemical tool for the definition of high gold-potential areas on both a regional and local scale is that

of basal till geochemistry. Although this program represents an ongoing study of the basal till geochemical signature of the Agassiz Metallotect the results indicate that independent of the scale of the geochemical survey undertaken in basal till samples (collected with a shovel) the analysis of gold by INAA in the heavy mineral fraction or arsenic by AAS in the clay-sized fraction (less than 2 microns) will effectively delineate areas of high gold potential. Gold and arsenic anomalies effectively overlap one another indicating either element in the respective mineral fraction could be utilized independently in the search for Agassiz-type mineralization. To date, anomalies ranging from 50 m to 0.5 km wide have been delineated down-ice from the Agassiz Metallotect (Fedikow, 1984; E. Nielsen, pers. comm.).

The results of rock geochemical studies at the Agassiz deposit are currently undergoing interpretation and will be released as an open file report upon completion.

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APPENDIX I: LOG AND SAMPLE LOCATIONS FOR DDH U82-5

0' - 160' (0 - 48.8 m)	dark grey-green, amphibole-rich rock (basalt) marked by textural coarsening to bottom of interval; variable amount of sulphide, carbonate and chlorite mottling (3 - 5% Py-Po); some epidotized fragments crosscut by siliceous-chlorite veins 36' - 40', 78' is biotite-rich; at 137' brecciated Py-Po bands in a biotite-rich layer; AGC-1 to 8
160' - 220' (48.8 - 67.1 m)	fine grained basalts with sections of epidote, 1-2% Po; 177' - 178.5' possible intrusion; silicification; local high concentrations of biotite; patchy distribution of Py-Po; strongly magnetic matrix in places; carbonate patches; AGC-9, 10, 10D, 11
220' - 280' (67.1 m - 85.3 m)	medium grained to fine grained amygdaloidal basalt; biotite-rich sections scattered throughout; silicification; epidote, 1/4" - 1/2" chlorite-pyrrhotite folia; white quartz veins with Py-Po and wallrock fragments from 277' - 279' and 268' - 270'; AGC-12, 13, 14
280' - 300' (85.3 m - 91.4 m)	tuffaceous, chlorite-biotite sedimentary rocks; pseudo-fragmental disrupted layers; transposed? siliceous sections cross-cut with pyrrhotite-chlorite veinlets with minor carbonate; AGC-15
300' - 325' (91.4 m - 99.1 m)	mixed interval of amygdaloidal basalt with clastic, pseudo-fragmental sedimentary rocks with 1/8" subhedral to euhedral magnetite crystals; minor Po; AGC-16, 16B
325' - 345' (99.1 m - 105.2 m)	chloritic, dark green amygdaloidal basalt; brecciated with white carbonate filled interstices; AGC-17

345' - 352' (105.2 m - 107.3 m)	clastic sedimentary rocks with subhedral and euhedral magnetite crystals, disrupted layers are carbonate and carbonate-rich; fragments have a maximum dimension of 1"; AGC-18
352' - 360' (107.3 m - 109.7 m)	medium grained, massive, foliated basalt
360' - 380' (109.7 m - 115.8 m)	massive basalt with chloritic and biotite-rich sections - pervasive, cross-cutting, not discrete layers; AGC-19
380' - 498' (115.8 m - 151.8 m)	basalt; chloritic, continuous and disrupted white and brown carbonate bands; patchy biotite; 1/8" diameter pink/red garnets; amygdaloidal in part; epidote; AGC-20 to 25
498' - 502' (151.8 m - 153 m)	biotite-rich sedimentary rocks; 1/8" pink garnets
502' - 530' (153 m - 161.5 m)	amygdaloidal, basalt with numerous 1/2" thick white carbonate veinlets; chlorite-pyrrhotite filled fractures at 505'; AGC-26, 26S
530' - 542' (161.5 m - 165.2 m)	clastic and chemical sedimentary rocks characterized by interlayering of biotite-chlorite-rich layers with garnets (basaltic tuff?) and carbonate layers; occasionally 1/8" thick Py-Po laminae in mafic layers; AGC-27, 27S
542' - 570' (165.2 m - 173.7 m)	massive, foliated and amygdaloidal basalt; 1" - 2" thick sections of biotite-rich sedimentary rocks(?) abundant white carbonate veinlets; 565' - 570' a "mixed" zone of basalt and sediments; AGC-28
570' - 580' (173.7 m - 176.8 m)	chlorite- amphibole-rich sedimentary rocks(?) with 1/4" thick cross-cutting Po folia; scattered pink garnets; AGC-29S

580' - 617' (176.8 m - 188.1 m)	amygdaloidal/porphyritic basalt; 1/4" - 1/2" white carbonate veinlets; less than 1% disseminated Fe sulphides; AGC-30, 30D, 31
617' - 628' (188.1 m - 191.4 m)	biotite- chlorite- amphibole- carbonate-rich sedimentary rocks with 3-5% disseminated Po-Py; 1/8" - 1/4" pink garnets (basaltic tuff?)
628' - 634' (191.4 m - 193.2 m)	basalt; AGC-32, 32S
634' - 637' (193.2 m - 194.2 m)	biotite- chlorite- amphibole- carbonate-rich sedimentary rocks (basaltic tuff?)
637' - 639' (194.2 m - 194.8 m)	basalt
639' - 641' (194.8 m - 195.4 m)	sedimentary rocks characterized by inter-layered chlorite-amphibole and cherty siliceous magnetite-bearing layers
641' - 660' (195.4 m - 201.2 m)	massive basalt; 8" white carbonate-breccia zone; AGC-33
660' - 669' (201.2 m - 203.9 m)	amygdaloidal basalt
669' - 670' (203.9 m - 204.2 m)	chlorite-biotite-carbonate-rich sedimentary rocks with euhedral to subhedral magnetite grains; 1% disseminated Fe sulphides; AGC-34
670' - 679' (204.2 m - 207 m)	amygdaloidal basalt
679' - 686' (207 m - 209.1 m)	carbonate- chlorite- biotite-rich sedimentary rocks with less than 1% disseminated Fe sulphides; 1/8" diameter pink garnets (basaltic tuff?)

686' - 690' (209.1 m - 210.3 m)	massive foliated basalt; AGC-35
690' - 691' (210.3 m - 210.6 m)	chlorite-biotite-amphibole-garnetiferous sedimentary rocks (basaltic tuff?)
691' - 700' (210.6 m - 213.4 m)	foliated basalt/basaltic tuff; very minor disseminated sulphides
700' - 711' (213.4 m - 216.7 m)	foliated and amygdaloidal basalt; AGC-36
711' - 718' (216.7 m - 218.7 m)	interlayered basaltic tuff and biotite-chlorite sedimentary rocks
718' - 722.5' (218.8 m - 220.2 m)	biotite-rich sedimentary rocks associated with a siliceous layer (quartz vein/chert) from 718' - 720'' 1/8" magnetite crystals (euhedral to subhedral); siliceous layer contains Po-Py laminae; Cp on slips-mobilizate
722.5' - 727' (220.2 m - 221.6 m)	altered basalt; numerous thin, white carbonate veinlets
727' - 728'3" (221.6 m - 222 m)	well layered chert and magnetite B.I.F.
728'3" - 747' (222 - 227.7 m)	altered basalt; up to 3" thick white carbonate veinlets and flecks of white carbonate; less than 1% disseminated sulphides; AGC-37
747' - 753' (227.7 - 229.5 m)	747' - 748.5' white weathering, bleached sedimentary rocks; fine grained; biotite-rich sections ("FELSIC"): AGC-38F
753' - 760' (229.5 - 231.6 m)	sedimentary rocks; 14" and 9" white carbonate bands interlayered with biotite-rich layers; thin chloritic layers, some mafic-basaltic tuff interlayers; AGC-38M

760' - 764' (231.6 - 232.9 m)	basalt/basaltic tuff with interlayered biotite-rich bands; at 763.5' - 1/4" - 1/2" pink garnets associated with chloritic layers in this interval
764' - 767' (232.9 - 233.8 m)	buff grey, structureless, fine grained sedimentary rock ("FELSIC"); AGC-39F
767' - 774' (233.8 - 235.9 m)	mixed FELSIC sedimentary rock and basaltic tuff; AGC-39
774' - 777' (235.9 - 236.8 m)	buff grey, structureless, fine grained sedimentary rock ("FELSIC")
777' - 788' (236.8 - 240.2 m)	mixture of "felsic" interlayered with biotite-rich zones, carbonate veinlets and infillings of breccia interstices; local high concentrations of biotite; scattered subhedral-euhedral magnetite grains
788' - 794.5' (240.2 - 242.2 m)	garnetiferous basalt/basaltic tuff; AGC-40, 40D
794.5' - 800' (242.2 - 243.8 m)	"FELSIC" sedimentary rocks interlayered with biotite- chlorite- amphibole-rich sedimentary rocks; less than 1% disseminated Fe sulphides
800' - 820' (243.8 - 249.9 m)	"FELSIC" (fine grained, structureless), sedimentary rocks with 1/4" - 3" layers of green, fine grained chlorite-amphibole-garnet-biotite; patchy euhedral-subhedral magnetite crystals; fine grained Py-Po associated with mafic layers; impression is that felsic is being altered/replaced by mafic material; thin white carbonate veinlets; barren, 10" white quartz vein at 810'; AGC-41
820' - 825' (249.9 - 251.5 m)	"FELSIC" with abundant biotite patches and 3" - 4" bands of <u>picritic</u> layers; quartz vein with Po at 824'

825' - 830' (251.5 - 253 m)	basalt/basaltic tuff interlayered with 1/4" white carbonate; AGC-42
830' - 840' (253 - 256 m)	FELSIC - possible fragments; picritic layers; carbonate; AGC-42F, 42P
840' - 855' (256 - 260.6 m)	basalt; layers, pods and veinlets of white carbonate; AGC-43
855' - 860' (260.6 - 262.1 m)	FELSIC with 1" layer of fine grained chlorite-amphibole; less than 1% disseminated sulphides (Fe)
860' - 866' (262.1 - 264 m)	basalt, foliated
866' - 875' (264 - 266.7 m)	altered FELSIC with numerous bands of carbonate and picritic rock; 1% sulphides; AGC-44
875' - 900' (266.7 - 274.3 m)	picrite; minor white carbonate veinlets; some biotite layers, quartz-carbonate zone at 883'; 1% sulphides; AGC-45
900' - 903' (274.3 - 275.2 m)	altered FELSIC
903' - 909' (275.2 - 277.1 m)	picrite with white carbonate flecks; AGC-46
909' - 911' (277.1 - 277.7 m)	altered FELSIC
911' - 920' (277.7 - 280.4 m)	altered FELSIC with minor carbonate, less than 1% disseminated sulphides
920' - 928' (280.4 - 282.9 m)	picrite with white carbonate along foliation plane
928' - 931' (282.9 - 283.8 m)	"altered" felsic(?) with chlorite-amphibole sections; sheared; AGC-47

931' - 967' (283.8 - 294.7 m)	picrite with white carbonate flecks; irregularly distributed carbonate veinlets; 950' - Po-Cp associated with cherty-siliceous interval; NSS veinlets of Py at 961' and 963'; AGC-48
967' - 972' (294.7 - 296.3 m)	cherty siliceous layer with chloritic and biotite-rich pods and narrow 1/4" layers with disseminated Py-Po; AGC-49
972' - 980' (296.3 - 298.7 m)	picrite with minor siliceous and biotite patches; 1 - 2% disseminated Py, Po
980' - 982' (298.7 - 299.3 m)	siliceous sedimentary rock (chert?) with chlorite-biotite-rich zones
982' - 989' (299.3 - 301.4 m)	picrite; foliated, carbonate veinlets
989' - 995' (301.4 - 303.3 m)	altered felsic with disseminated Py-Po; chloritic and biotite-rich veinlets; AGC-50C, 50P
(995' - 1026' (303.3 - 312.7 m)	picrite; occasional biotite- chlorite-rich sections; carbonate veinlets, silicified sections; AGC-51, 51D
1026' - 1027' (312.7 - 313 m)	altered felsic; biotite-rich; spotty carbonate veinlets; less than 1% disseminated sulphides
1027' - 1095' (313 - 313.8 m)	picrite; biotite- amphibole-rich foliation; locally intense carbonate as disrupted layers and veinlets; biotite-rich siliceous zones at 1064' (3") and at 1071' (7") generally much pervasive carbonate as disseminations and veinlets; maximum of 1% Po; AGC-52, 53, 54, 55, 55F
1095' - 1103' (333.8 - 336.2 m)	altered felsic 1% disseminated Py-Po; brecciated with whitish reaction runs on fragments -- with interstices filled with biotite and chlorite-rich material

1103' - 1120' (336.2 - 341.4 m)	picrite; biotite-rich sections; at 1110' laminated Po with chlorite-amphibole; disseminated Po-Py in biotite-rich sections; spotty disseminated carbonate and veinlets; AGC-56, 56F
1120' - 1142' 341.4 - 348.1 m)	altered felsic; 3% disseminated sulphides characterized by blebs and disrupted veinlets of Po-Cp (max. 8-10% sulphide in places); chlorite-biotite foliation; matrix contains disseminated biotite; AGC-57
1142' - 1164' (348.1 - 354.8 m)	picrite; white carbonate foliation (1/8") throughout less than 1% disseminated sulphides; biotite as disseminated flakes - some foliation; AGC-58
1164' - 1166' (354.8 - 355.4 m)	altered felsic; biotite-chlorite - 1% disseminated Py-Po
1166' - 1176' (355.4 - 358.4 m)	picrite; 5% disseminated Py-Po; AGC-59
1176' - 1180' (358.4 - 359.7 m)	altered felsic; biotite-chlorite folia; 1-2% Po
1180' - 1200' (359.7 - 365.8 m)	basaltic tuff/basalt; 1% Po; disseminated white carbonate flecks - foliated; AGC-60, 60D
1200' - 1210' (365.8 - 368.8 m)	altered felsic; biotite- chlorite-rich; 1-2% disseminated Po; disseminated white carbonate and as veinlets
1210' - 1227' (368.8 - 374 m)	picrite; white carbonate foliation; layers rich in biotite-chlorite-amphibole (actinolite); some massive sections of chlorite-actinolite; 1% disseminated sulphides; layers of massive chlorite-actinolite; 1224' - 1224.7" altered felsic; AGC-61
1227' - 1230' (374 - 374.9 m)	altered felsic, interlayered biotite-chlorite with siliceous layers

1230' - 1280' (374.9 - 390.1 m)	picrite; talcose ("sericite-chlorite"); spotty, coarse grained actinolite 1230' - 1240'; 1% disseminated sulphides; 1240' - 1260' massive chlorite + coarse grained actinolite - disseminated white carbonate flecks and discontinuous folia; 1260' - 1280' biotite-rich sections with 3-5% Py-Po; coarse grained actinolite is spotty; white carbonate as discontinuous folia and also as flecks; AGC-62, 63, 64
1280' - 1284.5' (390.1 - 391.5 m)	altered felsic; biotite-rich with 1/4" thick Po laminae
1284.5' - 1321' (391.5 - 402.6 m)	picrite; foliated; white carbonate folia; 1% disseminated Po-Py; 1311.5' - 1312' - altered felsic with brownish cast (carbonate?); coarse grained actinolite; disseminated white carbonate flecks and as folia; AGC-65, 66
1321' - 1324.5' (402.6 - 403.7 m)	altered felsic; biotite-rich sections and as wisps throughout felsic; 1% disseminated Py
1324.5' - 1326' (403.7 - 404.2 m)	picrite
1326' - 1327' (404.2 - 404.5 m)	altered felsic
1327' - 1348' (404.5 - 410.9 m)	picrite; coarse grained actinolite present; 1/4" white carbonate folia; 1344' - quartz vein with Po; 1% disseminated sulphides; AGC-67F, 67P
1348' - 1353.5' (410.9 - 412.5 m)	altered felsic; biotite-rich; AGC-68F
1353.5' - 1357' (412.5 - 413.6 m)	picrite; 1-2% disseminated Po; AGC-68P
1357' - 1359.5' (413.6 - 414.4 m)	altered felsic

1359.5' - 1363' (414.4 - 415.4 m)	picrite; patchy, coarse grained actinolite; 1% disseminated Po
1363' - 1393' (415.4 - 424.6 m)	altered felsic; 1363' - 1380 biotite-rich with maximum 5% disseminated Po-Py; coarse grained actinolite; biotite-rich; 1380' - 1393' biotite-rich patches with disseminated Po throughout interval; AGC-69, 70
1393' - 1395' (424.6 - 425.2 m)	picrite; 1% disseminated sulphides; AGC-70D
1395' - 1397' (425.2 - 425.8 m)	picrite; 1% disseminated sulphides
1397' - 1400' (425.8 - 426.7 m)	altered felsic; disseminated Po; biotite-rich
1400' - 1420' (426.7 - 432.8 m)	biotite-rich sedimentary rocks; chlorite-amphibole sections, disseminated Py-Cp; flecks and folia of white carbonate throughout; 1% disseminated sulphides; AGC-71
1420' - 1452' (432.8 - 442.6 m)	altered felsic, decrease in amount of biotite from last interval; 3-5% disseminated Py-Po in sections, disseminated white carbonate flecks and discontinuous folia throughout; biotite and picrite layers with Po; AGC-72, 73
1452' - 1465'5" (442.6 - 446.7 m)	picrite; 1% disseminated sulphides; disseminated white carbonate flecks - discontinuous folia
1465.5' - 1471 (446.7 - 448.4 m)	altered felsic, biotite and picritic sections; veinlet and disseminated Po in biotite-rich sections
1471' - 1474.6" (448.4 - 449.4 m)	picrite; biotite-rich patches (1/4" - 1")' AGC-74P, 74S

1474.6" - 1477'6" (449.4 - 450.3 m)	white; sugary textured quartz vein with chlorite-biotite-amphibole floats
1477'6" - 1482' (450.3 - 451.7 m)	picrite; disseminated white carbonate flecks and discontinuous folia; 1% disseminated Py-Po
1482' - 1483' (451.7 - 452 m)	sugary textured white quartz vein
1483' - 1485' (452 - 452.6 m)	lost core
1485' - 1497' (452.6 - 456.3 m)	picrite; 1% disseminated sulphides; disseminated white carbonate flecks - discontinuous folia; AGC-75
1497' - 1498' (456.3 - 456.6 m)	altered felsic; biotite-rich; 1% disseminated sulphides
1498' - 1499'6" (456.6 - 457.1 m)	picrite (as above)
1499'6" - 1505' (457.1 - 458.7 m)	altered felsic; biotite-rich in patches, picrite foliation; 1% disseminated sulphides
1505'6" - 1508'5" (458.7 - 459.8 m)	picrite (as above)
1508'5" - 1511' (459.8 - 460.6 m)	altered felsic; rich biotite patches; 1% disseminated sulphides
1511' - 1540' (460.6 - 469.4 m)	picrite; (as above); AGC-76P, 76S, 77
1540' - 1549' (469.4 - 472.1 m)	altered felsic; 1% disseminated sulphides, rich biotite patches; occasional white carbonate folia; AGC-78
1549' - 1556'6" (472.1 - 474.4 m)	picrite; coarse grained actinolite sections; 1% disseminated sulphides

1556'6" - 1557'5" (474.4 - 474.7 m)	altered felsic
1557'5" - 1566' (474.7 - 477.3 m)	picrite; sections of biotite-rich material; white carbonate veinlets; AGC-79P, 79S
1566' - 1580' (477.3 - 481.6 m)	biotite- chlorite- amphibole- carbonate-rich basaltic tuff(?), maximum 5% disseminated Py-Po; AGC-80, 80D
1580' - 1590' (481.6 - 484.6 m)	altered felsic; patchy picrite material and biotite, carbonate-rich zones
1590' - 1594' (484.6 - 485.9 m)	picrite; abundant white carbonate as disseminated flecks and disrupted folia; AGC-81
1594' - 1600' (485.9 - 487.7 m)	altered felsic; biotite-rich sedimentary rocks with variable amount of disseminated white carbonate and folia; 1% disseminated sulphides;
1600' - 1654' (487.7 - 504.1 m)	picrite; 1% disseminated sulphides; biotite-rich zones; disrupted white carbonate folia; 1640'8"-1654' picrite contains fine grained siliceous and white carbonate folia; AGC-82, 83, 84
1654' - 1660' (504.1 - 506 m)	fine grained, biotite-rich sedimentary rocks; inter-laminated Py-Po-Cp; 10-15% sulphide
1660' - 1680' (506 - 512.1 m)	predominantly sedimentary rocks with a picrite section from 1663' - 1664.5'; interlayered sediments with carbonate and picrite; 1% Py-Po; AGC-85
1680' - 1700' (512.1 - 518.2 m)	altered felsic as above; carbonate bands have maximum widths of 1"; AGC-86

1700' - 1746' (518.2 - 532.2 m)	altered felsics; occasional biotite-rich sections; otherwise as above; some picrite layers; scattered magnetite grains at 1729' - 1730'; 1721'5" - 1725'5" foliated picrite-siliceous-carbonate sedimentary rock; AGC-87, 88